White paper

Navigating a changing refrigerants market

A guide for selecting and accommodating alternative refrigerants for diverse heating and cooling applications

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Contents

1. Introduction

A massive change is currently underway in the refrigerants market. Driven by environmental concerns, legislation is pushing a gradual phase out of traditional refrigerants in favour of new alternatives with lower global warming potential (GWP).

The impact of these new rules will dramatically alter the way heating and cooling applications are performed in a wide range of industries over the course of the coming years. Businesses where these applications are central are thus facing a major question:

Which refrigerant makes the best sense for my needs?

Several options

While this is hardly the first time the refrigerants market has seen big changes, the current shift differs from past experiences in the sheer number of refrigerant options that are available. Historically, the market has largely seen one-to-one transitions. For example, when R22 was phased out, R407C became the standard replacement. This allowed for a relatively easy process throughout the entire supply chain, with direct components making quick and simple retrofits possible.

Today, the reality is much more complicated. Regulatory guidelines mean that businesses face different requirements depending on where and how they operate. A large number of new refrigerants have emerged, along with new technology to support them. But solutions that work well for some applications may not adequately support other demands. Simply put, there is no one-size-fits-all answer.

This whitepaper seeks to demystify the confusing process of choosing the right replacement refrigerant for a specific application. The following chapters will provide a useful overview of existing legislative requirements and current market trends before offering a breakdown of different low-GWP refrigerants available today. Lastly, this text will look at new technologies for using alternative refrigerants in various heating and cooling applications.

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2. Regulatory overview

The complexity of the changing refrigerants market is driven in part by the ongoing development of legal frameworks, including the 2016 Paris climate accord. In order to prevent global temperature increase from exceeding 2 °C above pre-industrial levels, signatories to the agreement are responsible for setting national targets to limit greenhouse gas emissions. This has contributed to the increased international focus on HFC (hydrofluorocarbon) refrigerants that contribute to global warming.

However, there is currently no global standard for which refrigerants must be phased out and by when. Instead, the situation is vastly different from country to country. The regulations that apply to a given business – as well as the options available to them – depend entirely on where they operate and the application in which the refrigerant is used.

Kigali amendment to the Montreal Protocol

One major effort to curb high-GWP refrigerants has been a 2016 amendment to the Montreal Protocol. In force since 1989, the Montreal Protocol on Substances that Deplete the Ozone Layer was originally developed to phase out ozone-damaging refrigerants like CFCs (chlorofluorocarbons) and HCFCs (hydrochlorofluorocarbons). While the protocol has been almost universally successful worldwide, HFCs became the primary replacement for these earlier refrigerants.

At the 28th Meeting of the Parties to the Montreal Protocol in the Rwandan capital of Kigali, the protocol was amended to target planet-warming HFC gases. The new agreement involves a phase out of HFCs by 2047, with different timetables for different countries. Highly developed regions must reduce production and consumption of HFCs beginning in 2019. Much of the rest of the world, including China and Brazil, will freeze HFC use by 2024. A smaller group of countries that includes India has until 2028 to institute a freeze.

Although the updated Montreal Protocol provides a timetable, the Kigali amendment was not as ambitious as initially anticipated. For businesses, this has meant a lack of clarity regarding expectations as well as the alternatives available to them. In particular, the protocol does not define what constitutes a suitable 'low-GWP' refrigerant for replacing HFCs. For the time being, these issues have been left to the determination of regional and national legislatures.

EU Regulation

Currently, the European Union's regulation on fluorinated greenhouse gases represents the most substantial requirements for curbing HFC usage. Originally adopted in 2006, it was updated in 2014 to set concrete GWP limits for acceptable replacement refrigerants.

While the regulation applies to all companies operating within EU member states, specific GWP levels as well as the deadlines for meeting them differ with regard to the application in question, as shown in the following table. European businesses weighing alternative refrigerant options must therefore consider that requirements will depend on the manner in which the refrigerant is used.

Table 2.1: GWP limits for refrigerants in the EU

Application	GWP Limit	Deadline
Domestic refrigeration	150	2015
Stationary refrigeration[1]	2500	2020
Hermetically sealed commercial refrigeration	150	2022
Centralized commercial refrigeration[2]	150	2022
Moveable room AC	150	2020
Single split AC[3]	750	2025

[1] *≥ –50°C*
[2] *≥40 kW. Exception in place for the primary circuit of cascade systems, where refrigerants with a GWP <1500 may be used.*
[3] *<3 kg of fluorinated greenhouse gases.*

GWP targets in Japan

Lawmakers in Japan have also taken steps to lower the climate impact of refrigerants. Unlike the EU, however, they have stopped short of instituting an outright ban of HFCs with strict GWP limits. The current situation in Japan entails softer GWP targets for different heating and cooling applications. These can be seen in the table, below.

Table 2.2: Japanese GWP targets

Application	GWP Target	Target Year
Room air conditioning	750	2018
Commercial air conditioning[1]	750	2020
Condensing units	1500	2025
Refrigeration units >1.5 kw	1500	2025
Cold storage warehouse[2]	100	2019
Mobile air conditioning	150	2023

[1] *Includes offices and stores*
[2] *>50,000 m^3*

3. Market trends

As the previous chapter indicates, the first step for selecting a new refrigerant is to consider which alternative makes the most sense for the intended application according to local requirements. However, even within application areas, there are often a number of options to choose from that will comply with national or regional regulations.

It is therefore important to consider how a decision may impact competitive advantage: *How do I want to position my product in the market? How do I want to differentiate myself from my competitors?* The answers to these questions can play a big role.

Within heating and cooling application areas today, there are a number of clear trends that provide a starting point for finding these answers.

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Heat pumps

In the heat pump markets of highly developed regions, R32 (difluoromethane) has emerged as the leading alternative to the previous standard for heat pump applications, R410A. However, R32 is not the only option available. Companies looking to differentiate their business have increasingly selected R290 (propane) instead, due to a substantially lower GWP than R32. The contrasting advantages and drawbacks of these options will be discussed in greater detail in chapter 4.

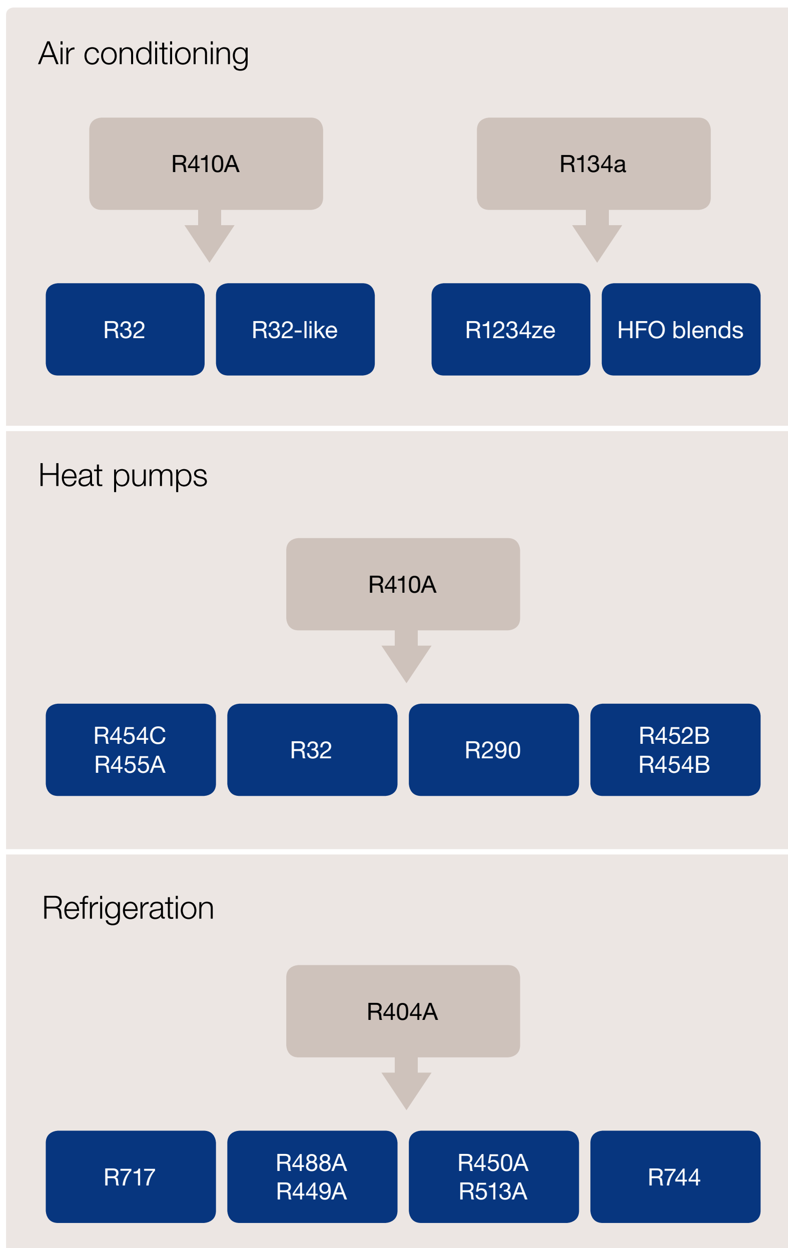
Air conditioning

Development for air conditioning in advanced markets has been similar, with previous users of R410A choosing R32 or R32-like refrigerant options. In applications involving R134a (1,1,1,2-Tetrafluoroethane), however, the trend has been toward HFO (hydrofluoroolefin) blends, such as R1234ze (1,3,3,3-Tetrafluoropropene).

Refrigeration

In contrast to the air conditioning and heat pump markets, the decisive trend in refrigeration has been in favour of natural refrigerants, a category which will be explored more in the following chapter. While some businesses have begun employing options such as R448A and R450A in place of the hydrofluorocarbon-based R404A, companies looking to set themselves apart from the competition have instead selected natural options like R744 (CO_2) and R717 (ammonia).

Table 3.1: Recent movement in the refrigerants market by application area



4. Refrigerant categories

While there are a large number of individual options for alternative refrigerants, it is possible to organize these into three main categories: high-density refrigerants, low-density refrigerants and natural refrigerants.

Understanding the different options according to these categories greatly simplifies the process of selection. It also offers a chance to more clearly illustrate the potential opportunities – and the potential risks – that each alternative presents.

High-density refrigerants

High-density refrigerants represent the first main category of alternatives on the market today. The most prominent of these is R32 or difluoromethane. There are also a number of similar, so-called R32-like refrigerants that fall into this category.

As an organic compound with zero ozone depletion potential, R32 offers clear environmental benefits compared to earlier CFCs or HCFCs. R32 also transfers heat more efficiently than refrigerants such as R410A, meaning it can help dramatically reduce energy consumption in, for example, air conditioning applications.

However, R32 also presents new challenges. Like many alternative refrigerants, it is mildly flammable. The right equipment and proper safety measures are therefore essential.

Additionally, businesses should consider that R32 has a GWP of 675. This is significantly lower than R22 or R410A, but it means that R32 is not be appropriate for applications where, for example, the European Union limits or Japanese targets have set thresholds of 150 or lower. Businesses looking for an environmental argument to differentiate their production from the competition may likewise want to consider alternatives with a lower GWP.

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Low-density refrigerants

The second category of today's alternative refrigerants are the low-density variety. This term largely refers to HFOs (hydrofluoroolefins) and HFO blends. Like HFCs, HFOs are composed from hydrogen, fluorine and carbon. However, as an unsaturated compound, HFOs are more reactive due to the presence of a carbon-carbon bond.

This also means that HFOs are a more environmentally-friendly alternative to both HFCs and CFCs. Like higher density refrigerants, they offer an ozone depletion potential of zero. In addition, the GWP of HFOs can be as low as 0.1% of comparable HFCs.

It is nevertheless important to keep in mind that the exact GWP will vary depending on the HFO blend in question. For example, R1234ze (1,3,3,3-Tetrafluoropropene) has a GWP above 150. For businesses operating in the European Union or Japan, it may therefore not provide a suitable long-term solution in some applications.

Furthermore, there are once again safety issues to consider. Like R32, the flammability of some HFOs can be a risk if not properly accounted for. A secondary concern is that HFOs can decompose under high temperatures, resulting in the formation of hydrogen fluoride and, subsequently, dangerous acids.

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Natural refrigerants

Business seeking to minimize the global warming potential of their heating and cooling applications have largely turned to natural refrigerants, the third main category of alternatives. Generally speaking, the term natural refrigerant is used today in reference to three options: R290 (propane), R717 (ammonia) and R744 (CO_2).

These three natural refrigerants offer the lowest GWP levels available on the market today. Propane has a GWP of just 3, CO_2 has a GWP of 1 and ammonia's is 0. The use of these refrigerants, however, entails a number of other trade-offs that require further consideration.

Propane, of course, is a highly flammable substance. While it creates a more sustainable option when used as a refrigerant, it thus also entails safety considerations similar to those noted above. As we will see in the next chapter, propane also presents technical demands similar to those of high-density refrigerants when designing a system.

While flammability concerns are not an issue for ammonia, the compound is highly toxic. As a result, the risks associated with leakage are far more drastic than with many other types of refrigerants. In addition, ammonia is corrosive and thus may not be conducive to use with certain types of equipment.

CO_2 can be used as a refrigerant without the safety implications of the other natural refrigerants, but it requires operation at pressures as high as 130 bar (1880 psi). This, in turn, creates another set of technological challenges.

Natural refrigerants offer the lowest GWP levels available on the market today.

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5. Technological solutions

Previous one-to-one changes in the refrigerant market often made it possible to retrofit existing equipment to support a new type of refrigerant, depending on the application. As the previous chapters make clear, the demands posed by many new refrigerants will in most cases require intensive redesigns of heating and cooling systems.

The number of new refrigerants further complicates matters here. Because the nature of the challenges can vary widely between different refrigerants, equipment designed for certain options may not be suitable for others. As a result, many businesses may feel further pressure to make the 'right' selection of a refrigerant for fear that they will become locked in to whatever they choose.

Due to such issues, many companies are looking to suppliers who can offer so-called multi-refrigerant platforms. These are heat exchangers developed to support the largest possible number of alternative refrigerants, with a wide range of features that make it possible to tailor each unit to meet a specific customer's needs. With a multi-refrigerant platform, it can become simpler to switch to a new refrigerant if an initial choice proves less than optimal for a particular application.

Movement toward brazed plate designs

In addition to the trends noted in chapter 3, two further factors will impact the refrigeration market in the coming years. The first issue is cost. Prices of alternative refrigerants are rising rapidly, and in some cases, the cost can be as much as ten times that of existing HFCs. At the same time, availability is a growing concern, with major shortages of refrigerants expected in the coming years.

In response, there has been growing movement toward brazed plate heat exchangers in place of traditional heating and cooling solutions, such as shell-and-tube models. Brazed heat exchangers offer a more compact design and smaller footprint. As a result, a lower refrigerant charge is needed to perform the same duties as other technology, providing an economical and more efficient solution for companies facing rising refrigerant costs or availability concerns.

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Important features

Within the brazed plate designs available on the market today, there are several additional elements that require consideration. Ultimately, the advantages of a multi-refrigerant platform come down to the features that can be found inside the heat exchanger – not what is visible from the outside. Recent advancements in plate heat exchanger technology provide several things to weigh, depending on the intended application and the category of refrigerants.

Plate asymmetry

The asymmetrical flow pattern of certain plate designs enables higher levels of efficiency in operation, but only if the asymmetry has been optimized for the application and refrigerant in question. For example, due to safety concerns noted in chapter 4, high-density and propane refrigerants must operate with a very low refrigerant charge. For this to work effectively, the plate asymmetry needs to squeeze the flow channels. Low-density refrigerants, conversely, require more open channels to achieve optimal efficiency.

A design built to support multiple asymmetries, such as Alfa Laval's patented FlexFlow™ pattern, is therefore key to enabling the most efficient performance, regardless of which refrigerant is chosen. Working with a supplier who has the capability to fully adapt a channel plate pattern makes it possible to achieve the optimal multi-refrigerant platform when designing a new system.

FlexFlow™

Stainless steel design

Brazed heat exchangers are frequently built with copper. While this is suitable for many newer refrigerants on the market, copper will react negatively with ammonia, which is highly corrosive.

A completely stainless steel model like Alfa Laval's AlfaNova™ offers a good solution in, for example, refrigeration applications where ammonia is an ideal refrigerant. The durability of brazed heat exchanger designs further guards against leakage, ensuring safer operation for this toxic refrigerant.

Alfa Laval AlfaNova™

AlfaNova®

High-pressure strength

As mentioned in the previous chapter, there are a number of strong environmental arguments for the use of CO_2 as a refrigerant, but it demands extremely high pressures in operation. To accommodate this, a durable channel plate design that is specially optimized for high-pressure duties is a must. In many cases, however, creating a stronger plate requires additional raw material, leading to a bulkier heat exchanger with a larger environmental footprint.

PressureSecure

As noted, the small footprint of brazed heat exchangers is important to reducing the required refrigerant charge. Fortunately, a number of advancements in today's plate designs have made it possible to strengthen the channel plate without necessitating additional raw material and, as a result, a larger unit. Alfa Laval's PressureSecure design capabilities are one such example.

Customized distribution system

DynaStatic™

A final design feature to keep in mind is the heat exchanger's distribution system. There is no one-size-fits all distribution design, and the type of refrigerant as well as intended application can play a large role. Alfa Laval's unique DynaStatic™ production makes it possible to fully tailor the distribution system to fit the purpose. While this may initially seem like a small detail, it helps ensure the optimal level of efficiency for any alternative refrigerant.

Ultimately, the advantages of a multi-refrigerant platform come down to the features that can be found inside the heat exchanger.

6. Conclusion

At first glance, the number of new, low-GWP refrigerants entering the market seems like a daunting challenge for businesses with crucial heating and cooling demands. Indeed, with so many available options, each with their own corresponding demands, the potential risks of choosing wrong can be quite intimidating.

On closer inspection, however, it is possible to see the current changes in the market as a tremendous opportunity – a chance to differentiate an offer and get ahead of competitors. While each alternative refrigerant presents a number of potential drawbacks, they also provide distinct advantages. With the help of a well-designed, modern multi-refrigerant platform, the right features and a capable supplier, it is possible to minimize those drawbacks while simultaneously maximizing the advantages.

7. Contact Alfa Laval

If you have any questions or would like to discuss heat exchangers for you plant, please contact us. You can find contact information for your nearest Alfa Laval representative on our web site: www.alfalaval.com.

We look forward to hearing from you.

About Alfa Laval

Alfa Laval is a leading global provider of specialized products and engineering solutions.

Our equipment, systems and services are dedicated to helping customers to optimize the performance of their processes. Time and time again. We help our customers to heat, cool, separate and transport products such as oil, water, chemicals, beverages, foodstuff, starch and pharmaceuticals.

Our worldwide organization works closely with customers in almost 100 countries to help them stay ahead.

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