

F-GAS REGULATION SHAKING UP THE HVAC&R INDUSTRY



The Greens | European Free Alliance
in the European Parliament



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Introduction by Bas Eickhout

Our environment might be in dire straits, but that doesn't mean that European environmental legislation is seen as a priority. Since the start of the economic crisis the EU's environmental ambitions have been scaled down significantly. Politicians focus on economic policies and regard environmental regulations as detrimental to economic recovery, they believe it hampers development and growth. The opposite is true: good environmental legislation highlights the path of sustainable growth that industry inevitably needs to take.

In 2013, I was the European Parliament's lead negotiator on the revision of the F-Gas Regulation. It was an uphill fight. F-gases are the low hanging fruits of climate action: alternatives are available and 0.5°C of global warming is avoided by using them. But, as always during negotiations on laws affecting vested interests, a lot of scaremongering was communicated to the negotiators. No efforts were spared to avoid an F-Gas Regulation that would actually change something. The 'highlight' of this dubious lobby was The Adventures of Brock 'n Ollie, a cartoon series starring two broccoli stalks making incorrect statements on behalf of the conservative part of the f-gas industry.

Nonetheless the European Parliament's negotiation team managed to strengthen the original proposal from the European Commission. Usually, in economic heavy times, Commission proposals are watered down once Council and Parliament

start discussing and lobby organization Business Europe wakes up. The F-Gas Regulation is one of the few climate laws agreed upon during the seventh term of the European Parliament (2009-2014). This regulation therefore forms a unique opportunity to see what ambitious environmental law actually does to industry.

This study looks at how sectors working with f-gases changed during the years that the regulation was negotiated and implemented. The results are promising. There is a large increase in suppliers and stores working with natural alternatives. The quality of alternatives is improving rapidly, while costs are falling. Industry calls the regulation a game changer. And international competitiveness? The F-Gas Regulation inspired lawmakers in Japan, California and Australia. Adoption of our European law also boosted international negotiations. F-gases will soon fall under the Montreal Protocol, which will start a global phase-down and open up opportunities for those European companies that are currently leading the way.

What should we take away from this? Our society is facing huge challenges. Climate change. Resource scarcity. Loss of biodiversity and ecosystems. Soil, air and water pollution. These problems won't be solved with a laissez-faire attitude. The study proves that ambitious environmental legislation drives innovation and gives companies an international advantage. Environmental policy is beneficial for those open to change.

Bas Eickhout,
Member of the European Parliament

Introduction by shecco

The world is on the verge of agreeing a global legally binding deal that would put an end to climate-damaging gases commonly used in heating and cooling equipment. It is therefore an appropriate moment to take a note of the effect that progressive EU legislation in this area has had on the industry and other legislative frameworks. The report *F-Gas Regulation shaking up the HVAC&R industry* explores a range of areas while highlighting industry feedback and progress to date.

Whilst not even two years have passed since the entry into force of the EU F-Gas Regulation, the changes in the industry are noticeable. The impact is expected to get even more pronounced as the adopted measures switch into high gear in the years to come. Nevertheless this report serves to demonstrate that with clear, ambitious and timely regulatory rules, the industry is able to take action much more quickly than expected.

Klara Skacanova,
Deputy Manager, Market Development, shecco
Lead Author

With over 650 companies working today with natural refrigerants across Europe (much more than in any other world region), Europe is clearly a global leader when it comes to cutting-edge HFC-free based equipment. This shows that early legislative measures help industry to gain a competitive advantage in local and global markets – an aspect that will become even more important with the forthcoming deal on a global HFC phase-down.

It is clear that not all the heating, cooling and refrigeration sectors are progressing towards low-carbon technologies at the same pace and there still is room for further action and improvement. Other regions, such as California, that have been inspired by the EU might soon outpace its progress if the EU legislative framework does not continue pushing the industry in areas where more innovation is needed.



Executive summary

Hydrofluorocarbons (HFCs) are the fastest growing source of greenhouse gases globally, but also one of the areas where climate-friendly, energy-efficient alternatives, such as natural refrigerants, are readily available for a growing number of applications. In 2014, the EU took regulatory action to limit the use of these gases through a combination of measures. The EU F-Gas Regulation, which entered into force in 2015, is rapidly changing the face of European industry and influencing markets beyond Europe's borders.

This report pinpoints some of the key areas in which the Regulation has had the most prominent impact, while highlighting reactions and expectations of a number of industry experts.

Industry working with HFC alternatives growing

Building on shecco's research from 2013, which collected information on 400 companies working with natural refrigerant technologies across European countries, this report updates the data and finds that there are now **more than 650 organisations that manufacture HFC-free technologies or offer services related to these systems**. Overall, this indicates that **the Regulation has helped create new green jobs in the heating, refrigeration and cooling sector**. It is worth noting that besides traditional markets such as Germany, Switzerland, and the Netherlands, **the number of companies working with natural refrigerants is also growing in the Southern Europe**. Here either new companies are emerging or the existing ones are increasingly shifting their product and R&D focus towards environmentally friendly technologies.

The first-movers who had invested in future-proof HFC-free solutions ahead of the EU-wide regulatory changes were able to reap the benefits of their competitive advantage already before the Regulation came into effect.



Bans on HFCs proving to be the most effective measure

50% of respondents to an industry survey believe that the overall phase-down of HFCs will have the most significant impact on the shift away from high-GWP refrigerants. Nevertheless the findings indicate that **the phase-down alone does not create enough pressure in the market to move towards future-proof low-GWP technologies, such as natural refrigerants.**

In the sectors where the F-Gas Regulation is putting in place bans on HFCs, the industry has indicated much stronger **growth in the availability of HFC-free technology over the last five years as well as a greater shift in R&D investments and employment with regard to this type of product.** The heat pump and air-conditioning sector could benefit from further regulatory action to spur innovation and increase the availability of HFC-free equipment.

Number of HFC-free stores using cutting-edge technology has tripled between 2013-2016

Supermarket refrigeration is an example of a sector where a ban on HFCs (GWP > 150) will start to apply as of 2022. **All surveyed companies active in this sector have indicated growth in availability of equipment using natural refrigerants over the past five years.** This is a clear sign that HFC bans are the most effective measure to move the market towards the ultimate climate-friendly technologies. CO₂ transcritical technology, which has become the mainstream HFC-free technology for the food retail sector, has enjoyed particularly strong growth. The findings show that the number of stores using transcritical CO₂ technology in Europe has tripled over the past three years, **reaching more than 8,730 such stores, or 8% of the European food retail sector.**

With around 11,000 stores using the CO₂-based technology worldwide, Europe is undoubtedly the technology leader. **This creates a strong competitive advantage for European companies as other regions are looking to move away from HFCs** in commercial refrigeration, which is the main sector for HFC use.

Technology innovation helps southern European countries move towards natural refrigerants

When the F-Gas Regulation was adopted, some industry members argued that in certain sectors it would be challenging for the warmer climates of Southern Europe to meet the requirements of the Regulation. The Regulation has in fact given a strong boost to **innovation in technologies for warmer ambient regions, with a number of companies introducing HFC-free solutions that have proven to work efficiently in temperatures of up to 44°C.**

While it had been previously argued that CO₂ technology is not a viable solution for the Southern European, the *Map of stores using cutting-edge HFC-free technology in Europe* clearly shows that the industry was able to overcome the challenge. The number of stores equipped with energy-efficient technology using CO₂ as a refrigerant has registered strong growth in countries like Spain, Italy and Romania.

Growing number of trained technicians

The current mandatory training and certification requirements under the F-Gas Regulation do not address safe handling of HFC-free technologies. Nevertheless, the industry has responded to the growing need for trained personnel with increased availability of training programmes and dedicated centres. **Four in five HVAC&R industry experts expect to see this number of people trained on natural refrigerants increase in the next one to two years. Almost 50% of those that do not provide or receive training on natural refrigerants plan to get involved in this type of training between 2016-2020.**

Global impact

A large number of companies operating in the HVAC&R sector are global businesses with activities around the world and the Regulation has influenced how they do business and what types of product they offer outside of Europe. Moreover, the Regulation has had an impact on other legislative frameworks by inspiring regulators from different regions and countries designing their own rules to limit the use of HFCs.

For the state of California in the US, the F-Gas Regulation is **“the best existing programme in the world to reduce f-gas emissions”**. With regulatory work ongoing, the California Air Resources Board has announced plans to introduce measures that would exceed the ambition of EU’s current legislation.

At international level, the work that the EU has done domestically serves as **a great example of what could possibly be done on a global scale to reduce HFC emissions and thereby avoid 0.5°C of global warming by 2100.**

Methodology

Quantitative and qualitative analysis

Market development company shecco undertook research to reveal the early effects of the EU F-Gas Regulation on the HVAC&R industry as well as on legislative frameworks outside of Europe. The research collected both quantitative and qualitative data to indicate areas where the Regulation has had the most significant impact.

shecco conducted quantitative research among manufacturers, component suppliers and technology providers to identify the number of companies working with natural refrigerants. In addition, through another quantitative analysis shecco evaluated the number of supermarkets using cutting-edge technology today while comparing the situation to the period before the F-Gas Regulation adoption.

To complement the quantitative data collection, shecco gathered additional evidence on the experience of European manufacturers and end-users through individual interviews, presentations at conferences and other available sources.

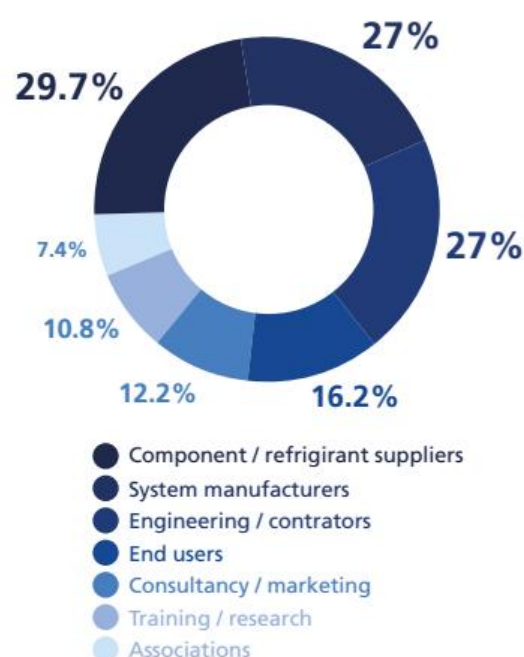
Industry survey

In order to reflect industry views on the impacts of the F-Gas Regulation in the EU and the effects it has had so far on the European businesses, shecco conducted an online survey that collected responses from over 230 industry representatives. The questionnaire was distributed to a wide audience of industry experts that provide or use HVAC&R services and products using both traditional HFC refrigerants as well as natural cooling fluids.

The respondents had the possibility to indicate whether they use natural refrigerants, synthetic low-GWP refrigerants (GWP < 150) or none of these two refrigerant groups in their main area of activity. The results show that **more than two-thirds of respondents use natural refrigerants**, while around one-third works with technologies that rely on synthetic low-GWP refrigerants. 24% indicated they use HFCs and have not made the transition to climate-friendly alternatives in their main area of activity.

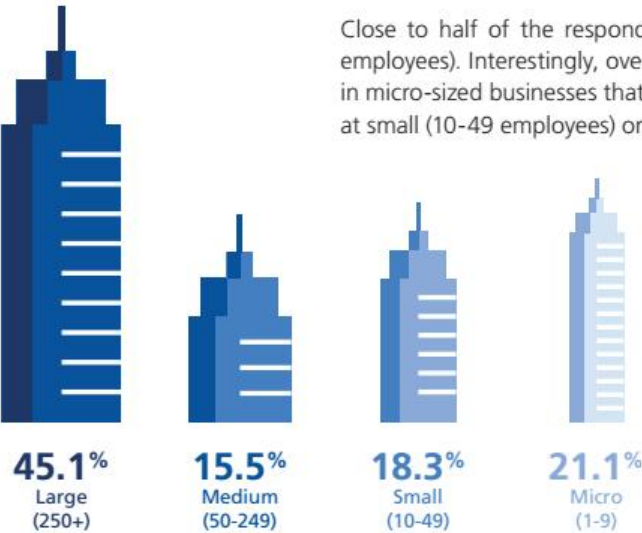
Profile of survey respondents

The survey asked respondents to identify the type of organisation they represent or are active in. Component / refrigerant suppliers, system manufacturers and engineers / contractors were the most represented groups to respond to the survey. The other categories included end users, consultancy / marketing, training & research as well as associations.



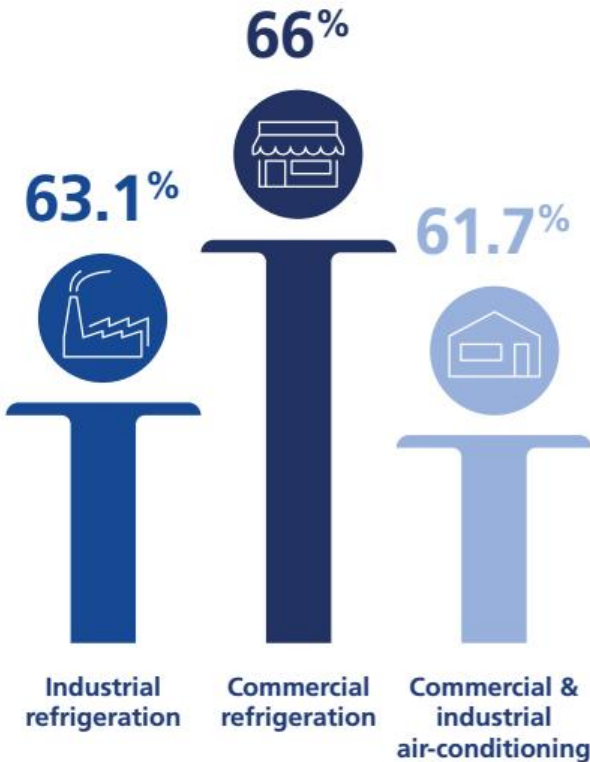
Size of companies

Close to half of the respondents were representatives of large companies (more than 250 employees). Interestingly, over 20% of the respondents that answered the questionnaire work in micro-sized businesses that employ 1-9 people. The remaining respondents typically worked at small (10-49 employees) or medium-sized companies (50-249 employees).



Key HVAC&R sectors represented

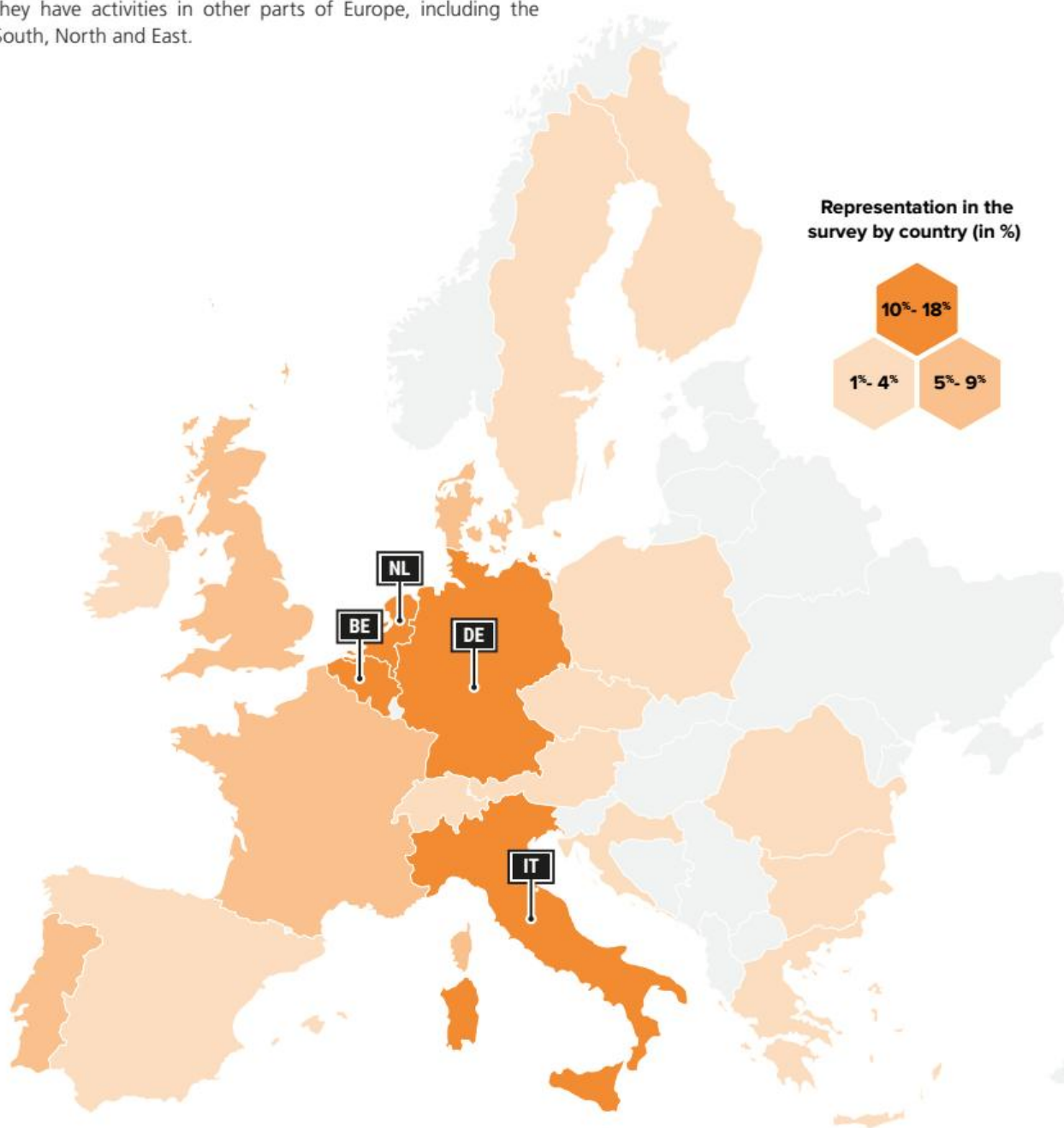
To better understand the division of applications that are represented in the responses, the survey asked respondents to identify the category they are active in. Commercial and industrial refrigeration and air-conditioning were the most well represented categories. Refrigeration as a whole was the most common choice. Commercial refrigeration had the highest proportion, with 66%, followed by industrial refrigeration and commercial & industrial air-conditioning, with 63.1% and 61.7% respectively. Residential and transport applications were not as common. Only residential heat pumps and residential AC showed higher representation, with 35.5% and 34% respectively.



Location of companies

Nearly two-thirds of companies that participated in the survey are headquartered in five European countries – the Netherlands, Germany, Italy, Belgium and the United Kingdom. The rest of the companies are located in France, Denmark, Portugal, Sweden and other markets. In general, a majority of the companies are based in Western Europe, with some in the Southern Europe. The central and eastern regions of the EU are not well represented.

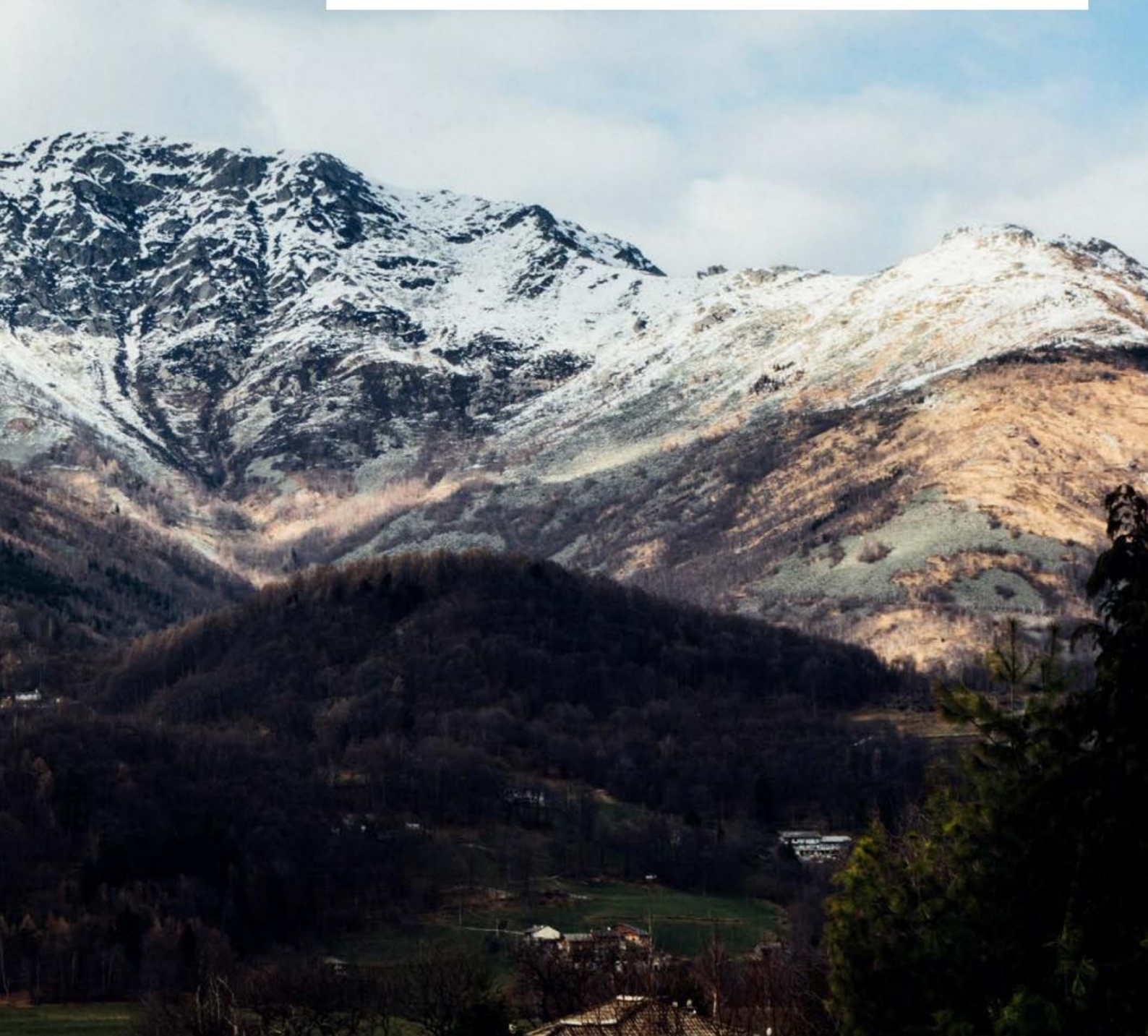
When asked about the region in Europe where the industry representatives provide or use most of their HVAC&R products and services, 70% of them indicated Western Europe, while a considerable share (around 50%) of representatives suggested they have activities in other parts of Europe, including the South, North and East.



CHAPTER 1

HFCs AND CLIMATE-FRIENDLY ALTERNATIVES

Fluorinated greenhouse gases, commonly referred to as f-gases, are man-made gases that do not damage the ozone layer, but are powerful greenhouse gases and are up to 15,000 times more powerful than CO₂ (based on a 100-year timescale measurement). The most common f-gases are hydrofluorocarbons (HFCs), which are the focus of this report. Other f-gases include perfluorocarbons (PFCs), which are often used in semiconductor applications¹, and sulfur hexafluoride (SF₆), commonly used in electrical switchgears².

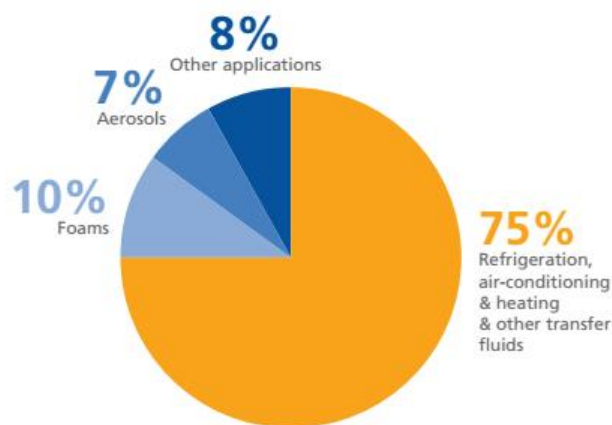


1.1 HFCs and climate change

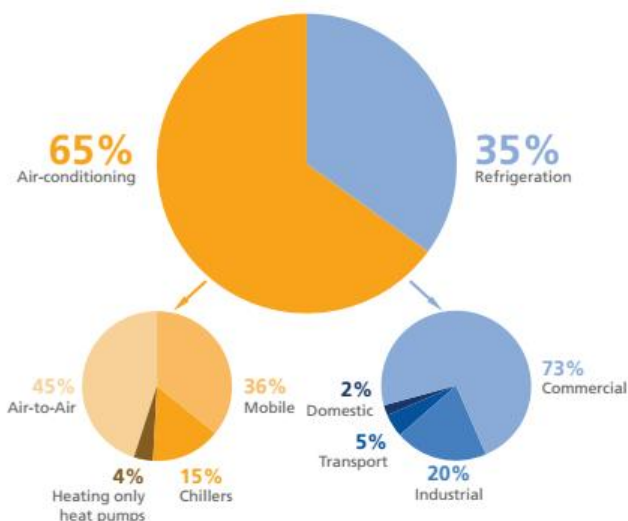
1.1.1 Applications of f-gases

HFCs are often used as refrigerants that are utilised in air-conditioning, refrigeration and heating equipment. They are also used as blowing agents for foams, as solvents, and in fire extinguishers and aerosols. Leakage of these gases during manufacturing, maintenance, regular usage, as well as during improper disposal and reclamation, results in emissions.

As shown in a European Environment Agency's report 'Fluorinated greenhouse gases 2014', approximately 75% of f-gases supplied to the EU market in 2014 had an intended use as refrigerants for refrigeration, air-conditioning, and heating. These were also entirely HFCs.



Total supply of intended application (% tonnes)



HFC use in RACHP sectors (GWP-weighted) – 2012

According to the United Nations Environment Programme (UNEP), 65% of the global HFC consumption (measured in global warming potential (GWP)) in the refrigeration, air-conditioning and heat pump (RACHP) sector is for air-conditioning and heat pumps, while 35% is from refrigeration.

Regarding HFC use in the air-conditioning sector, air-to-air makes up 45%, while mobile constitutes 36%. Within the refrigeration sector, commercial use makes up 73% of HFC use.

Overall, commercial and industrial refrigeration are the main sectors for HFC use, comprising over 90% of the total.

¹ Semiconductors have distinct electrical characteristics that are used to make computer chips, calculators, telephones, and medical equipment.

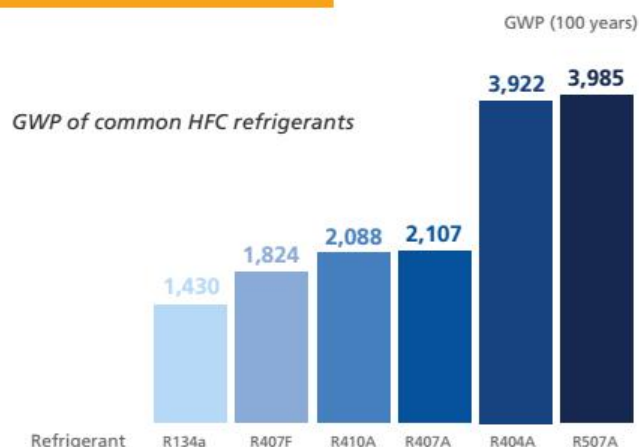
² The combination of electrical disconnect switches used to control and protect electrical equipment.

1.1.2 Why target HFCs?

The global reduction of HFCs can contribute to avoiding 0.5°C warming by 2100, representing an important contribution to global mitigation efforts.

With the phase-out of ozone-depleting substances (ODS) such as chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) under the Montreal Protocol on Substances that Deplete the Ozone Layer, the use of HFCs as main replacements has been increasing. In the EU and globally HFCs have become the fastest-growing source of greenhouse gas emissions. According to the European Environment Agency's 2014 report on fluorinated greenhouse gases, f-gases accounted for approximately 2.5% of all greenhouse gas emissions (expressed in global warming potential) in the 28 Member States in 2013. According to the European Commission, f-gas emissions have risen by 60% since 1990, in contrast to all other greenhouse gases whose emissions have been reduced.

HFCs, while not ozone-depleting, do have a very high negative impact on the climate. Their global warming potential (GWP) is usually measured over a period of 100 years with reference to CO₂. Nevertheless, considering the relative short lifetime of HFCs in the atmosphere, a shorter horizon, such as 20 years, would much better reflect the effects of these gases on the climate. For instance, R134a, an HFC currently accounting for over half of f-gases used in refrigeration, air-conditioning and heating, has an atmospheric lifetime of ~14-16 years. Its GWP over 100 years is 1,430 while the GWP over 20 years, which is much closer to its actual existence in the atmosphere, is 3,830.



HFCs are often identified as 'low hanging fruits' in the climate challenge given that alternatives to replace these high global warming gases are readily available for a growing number of applications and regions. The Paris Agreement reached among nearly 200 countries at the 21st Conference of the Parties (COP21) to the UNFCCC aims to keep the global temperature rise below two degree Celsius, while pursuing efforts to limit it to 1.5°C (compared to pre-industrial levels). The reduction of HFCs globally can contribute to avoiding 0.5°C warming by 2100, representing an important contribution to global mitigation efforts.

1.1.3 EU action to cut f-gas emissions

Under the Kyoto Protocol, the EU must reduce its overall greenhouse gas emissions by 80-95% by 2050 when compared to 1990 levels. The expected cumulative emission savings are 5 Gigatonnes by 2050 - this represents more than the CO₂ produced by a billion return flights from Paris to New York.

To reach this target, the Commission adopted a Roadmap for moving to a competitive low-carbon economy in 2050. The Roadmap specified that the EU should cut its emissions to 80% below 1990 levels through cost-effective reductions in specific sectors. Non-CO₂ emissions, including fluorinated greenhouse gases, should be reduced by over 70% to help reach this target.

To address growing emissions of fluorinated gases, the European Union adopted two key legislative acts – the Directive on mobile air-conditioning or the so called 'MAC Directive' and the Regulation on Certain Fluorinated Gases or the so called 'F-Gas Regulation'. After a 2011 evaluation had found that further action is necessary to slash emissions of f-gases, the European Commission put forward a proposal to revise the F-Gas Regulation. The new version of the Regulation came into force in January 2015.

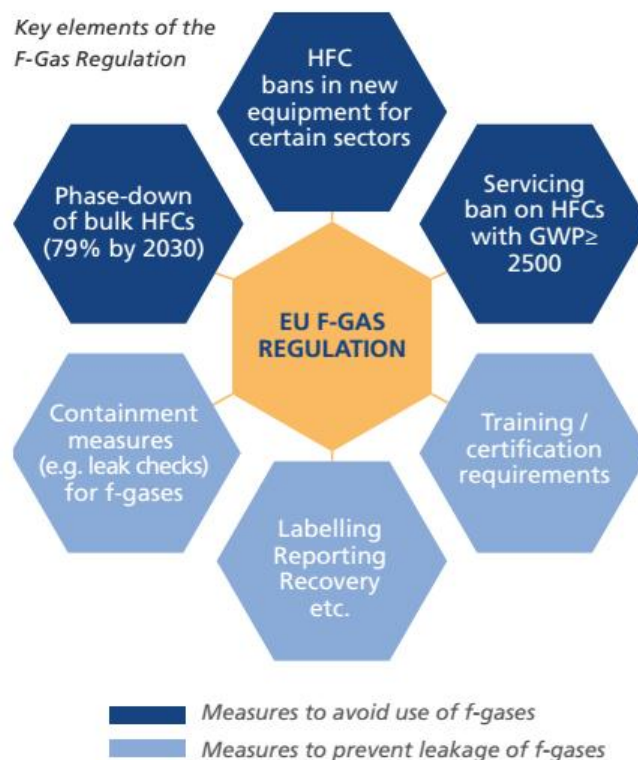
1.2 EU F-Gas Regulation and its key measures

The average global warming potential (GWP) of HFCs will have to fall from today's 2,000 to about 400 by 2030 across all sectors.

Adopted in April 2014, the Regulation (EU) 517/2014 on fluorinated greenhouse gases (F-Gas Regulation) replaced the first Regulation and strengthened the existing measures while introducing additional new elements. The Regulation's goal is to reduce the emissions of fluorinated gases by two-thirds by 2030 (in CO₂ equivalent; CO₂e).

The reduction of fluorinated gases is addressed through a combination of measures, which are complimentary and reinforce each other.

Key elements of the F-Gas Regulation



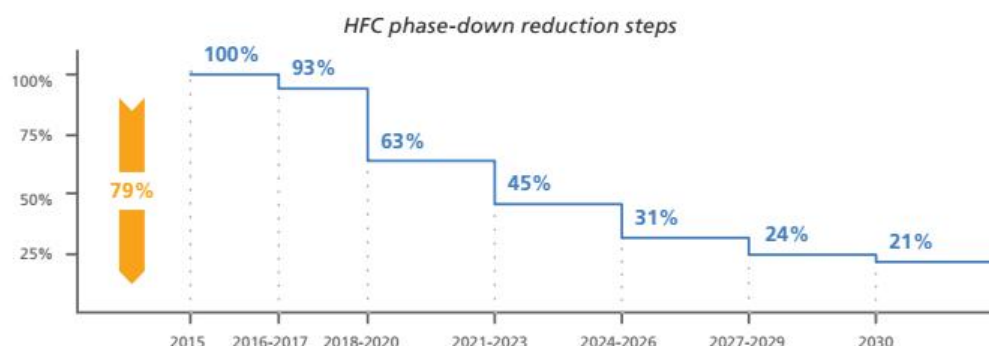
1.2.1 HFC phase-down

The **phase-down of hydrofluorocarbons (HFCs)** is considered to be one of the key pillars of the Regulation as it aims to reduce the amount of HFCs placed on the EU market (CO₂e) by 79% by 2030, as compared to average levels in 2009-2012. Producers and importers of f-gases are allocated annual quotas of HFCs that allow them to place a certain amount on the market. Starting in 2015 and running through 2030 these annual quotas are gradually reduced with a first reduction of 7% in 2016.

While the effects of the HFC phase-down might not be noticeable to end users and manufacturers at this point in time, this will change within the next three years. The first significant

cut in HFC quotas in 2018 – of 37% – is expected to have a major impact on the cost of HFCs, which will become less widely available. Considering that, as of 2017, the HFC phase-down needs to incorporate HFCs pre-charged in equipment, it is estimated that the cut in 2018 will equal 44%. Early action from manufacturers and end users is essential in anticipation of these future cuts in availability of HFCs in order to be able to reach the targets and comply with the Regulation.

What the phase-down actually means is that the average GWP of HFCs will have to fall from today's 2,000 to about 400 by 2030 across all sectors. Natural refrigerants will therefore play a major role in achieving this target.



1.2.2 HFC bans in new equipment

The F-Gas Regulation also introduces **bans in specific sectors on new equipment using HFCs above a specific global warming potential (GWP)** that will take effect by a certain year. This measure is crucial for ensuring that the HFC phase-down targets are achieved. The HFC ban specifies the timing for each sector to shift to refrigerants with a lower climate impact, such as natural refrigerants. Following an impact assessment by the European Commission and the compromise negotiations among the EU institutions, HFC bans have been introduced in several sectors where safe, energy-efficient and cost-effective alternatives are available across the EU.

In the refrigeration sector, the restrictions especially target the commercial sector, where the EU foresees that as of 2022 new equipment will use refrigerants with a GWP below 150

in both small plug-in applications (e.g. bottle coolers, vending machines) and in larger centralised systems in supermarkets (with some exceptions).

In the air-conditioning sector, the HFC ban addresses only small equipment, including portable air-conditioners³ and single split AC units⁴ with less than 3kg of refrigerant.

The Regulation intends to abolish the use of very high-GWP gases (GWP above 2,500) not only in new equipment but also in existing installations. As of 2020 it will be prohibited to service existing refrigeration equipment with HFCs that have a GWP of 2,500 or above, unless these refrigerants are recycled or reclaimed. Such HFCs could still be used until January 2030 in existing equipment.

HFCs bans in refrigeration and air-conditioning

SECTOR		GWP LIMIT	YEAR
Domestic refrigeration		150	2015
Stationary refrigeration (except < -50°C)		2,500	2020
Hermetically sealed commercial refrigeration		150	2022
Centralised commercial refrigeration (≥40kW), except in the primary refrigerant circuit of cascade systems where f-gases with a GWP<1,500 may be used		150	2020
Movable room AC		150	2020
Single split AC (< 3kg of f-gases)		750	2025

³ Small, easily movable air conditioners for residential use

⁴ System for room air-conditioning that consists of one outdoor and one indoor unit linked by refrigerant piping

1.2.3 Leakage reduction

While the HFC phase-down and bans aim to avoid the use of f-gases in new and existing equipment, several measures target leak reduction and prevention through improved maintenance and recovery of equipment, training and certification measures as well as labelling.

The Regulation strengthens the legal requirements to **prevent the intentional and unintentional release of HFCs**. Operators are required to take all precautions that are technically and economically feasible to prevent the unintentional release of HFCs.

Periodic leakage checks are required for certain types of equipment, namely stationary refrigeration equipment, stationary air-conditioning equipment, stationary heat pumps, stationary fire protection equipment, refrigeration units in refrigerated trucks and trailers, and organic rankine cycles. The frequency of leak checks is now based on the CO₂ equivalent (CO₂e) of the refrigerant used, whereas in the first Regulation the frequency of checks was based on the amount in kilograms of refrigerant used. This should better reflect the real climate impact of the gases.

Under the provisions of the EU F-Gas Regulation, manufacturers cannot place products and equipment on the market unless **properly labelled**.

In addition, **annual reporting** is required by 31 March each year on production, importation, exportation, destruction and feedstock use during the previous calendar year.

The EU F-Gas Regulation sets **mandatory requirements for training** of technicians and personnel involved in handling f-gas refrigerants.

The end-user sectors for which these training requirements apply include stationary refrigeration, air-conditioning, heat pumps, and refrigerated trucks and trailers using fluorinated gases. All technicians that carry out the activities on the equipment listed must hold an F-gas handling certificate.

The certification programmes and training should also cover information on relevant technologies to replace or reduce the use of fluorinated greenhouse gases and their safe handling. Nevertheless, the Regulation does not mandate the detailed training that may be necessary to safely use HFC-free refrigerants, such as hydrocarbons and CO₂. To this end, the European Commission shall examine EU and national legislation with respect to training on alternative refrigerants and could submit a proposal to amend the EU legislation, if necessary.

1.3 About natural refrigerants

Natural refrigerants do not deplete the ozone layer and have negligible or zero global warming potential.

The term 'natural refrigerants' is used to categorise non-synthetic substances that occur in nature's bio-chemical processes, unlike 'synthetic' or 'fluorinated refrigerants', which are man-made chemicals.

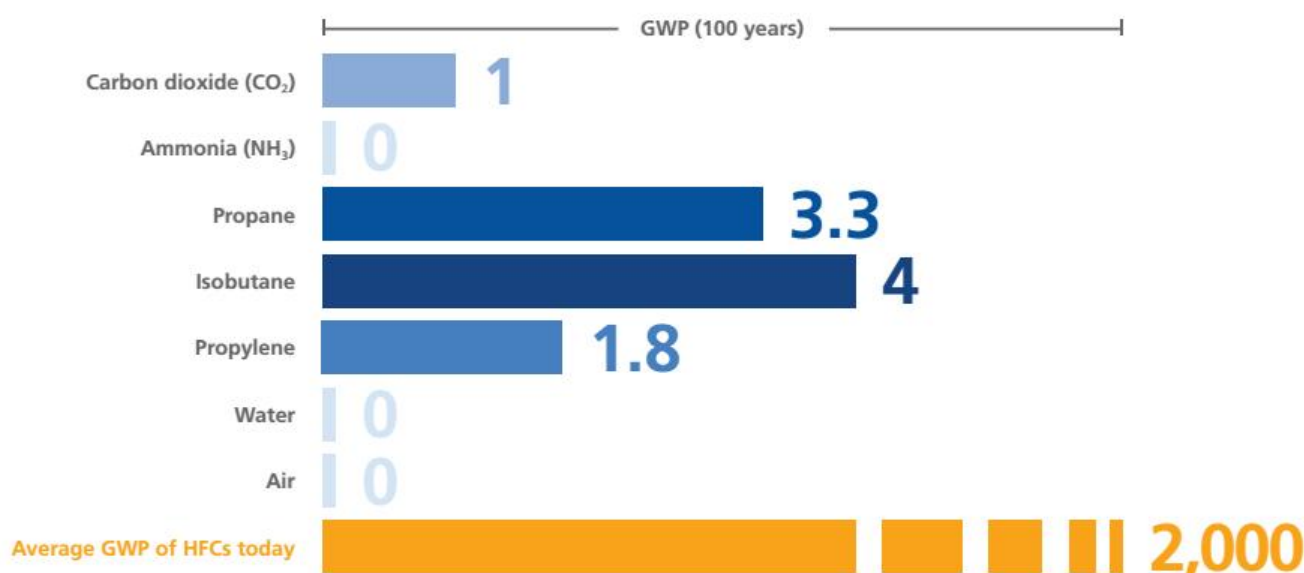
The most commonly used natural refrigerants today are ammonia (NH_3), carbon dioxide (CO_2) and hydrocarbons, such as propane, isobutane and propylene, also known as propene. In addition, water and air can be used as refrigerants and are already applied in a several commercially available applications, while they continue to be the focus of further R&D activities.

Natural refrigerants do not deplete the ozone layer and make a negligible – or zero in the case of ammonia, water and air – contribution to global warming. These products were used as refrigerants prior to the 1950s, before fluorocarbon refrigerants became commonplace. They are now being used more extensively due to their low impact on the environment, favourable thermodynamic properties and low cost.

Natural refrigerants represent a 'basket of solutions' with different characteristics that can cover a wide range of temperature needs for different types of application. The high efficiency of natural refrigerants also means that they make a lower indirect contribution to global warming.

The precision of the term 'natural refrigerants' is sometimes debated, given that, to be used as refrigerants, ammonia, carbon dioxide, and hydrocarbons also undergo an industrial purification and manufacturing process. However, today there is a well-established distinction between substances whose chemical properties and safety aspects have been studied in their entirety and those fluorinated gases. Given their chemical complexity and comparatively short period of usage, fluorinated gases have confirmed and/or unknown negative effects on ozone depletion, global warming and ecological safety, and therefore, are subject to continued debate.

GWP of natural refrigerants



1.3.1 Carbon dioxide (CO₂)

CO₂ is a non-flammable, non-toxic and environmentally benign natural refrigerant. With a global warming potential (GWP) = 1, CO₂ is the reference value for comparing a refrigerant's direct impact on global warming. CO₂ as a refrigerant is sourced as a by-product from a number of production methods.

When used as a refrigerant, carbon dioxide typically operates at a higher pressure than fluorocarbons and other refrigerants. Although CO₂ is a higher pressure refrigerant, only in a few parts of a CO₂ system will the pressure be higher than in a conventional system, and special components are available and used for that purpose. It is often claimed that high pressure equals high risk; however, many commercial applications today work safely with high pressure, including beer draughts in bars. Moreover, the higher pressure means that CO₂ systems and piping are more compact than current systems, leading to reduced material costs.

Key applications

The first CO₂ compression refrigeration system in Europe dates back to 1881. Until the 1950s, CO₂ was used in 60% of ship refrigeration plants and 10% of the land refrigeration plants. Today, CO₂ is established in various new applications, while there is continuous research and development ongoing to deploy the refrigerant on a wider scale. In Europe, the use of CO₂ in commercial refrigeration (centralised systems in supermarkets) has become particularly popular, while the refrigerant is also deployed in small to medium-sized industrial refrigeration plants, either as a sole refrigerant or in combination with ammonia. Besides these large equipment applications, CO₂ is a common refrigerant in plug-in commercial refrigeration equipment, such as vending machines, bottle coolers and display cabinets. Moreover, CO₂ heat pumps for residential, commercial and industrial use have been increasingly utilised and are poised to gain more popularity in the years to come. In transport applications, CO₂ has been used for refrigeration of goods in transit, while air-conditioning systems using the refrigerant have been developed for cars, buses and trains.

1.3.2 Ammonia (NH₃)

Ammonia is a colourless gas at atmospheric pressure. With zero ozone depleting and global warming potential, as well as a short atmospheric lifetime, it does not form any by-products or decomposition products with a negative environmental impact.

Ammonia is known for its higher toxicity, due to which its use is often prohibited in areas with public access, but can normally be used without limits in unoccupied spaces or outside. In occupied spaces, ammonia can be successfully and safely used in indirect systems in conjunction with other refrigerants (often CO₂) – ammonia refrigerant is safely contained in unoccupied closed room (or outdoors) and its amount is considerably smaller than in traditional ammonia systems. Moreover, in case of leakage, the strong odour of ammonia makes it easy to detect even in very small quantities.

Key applications

Ammonia was one of the first refrigerants to be used in mechanical systems. It has been deployed in cold storage and food processing industries since the 1900s. Today, more than 90% of large industrial refrigeration facilities in Europe use ammonia as a refrigerant. Besides food processing, cold storage and distribution, ammonia has found its place in breweries, wineries, ice rinks, chemical plants, cargo ships and fishing vessels as well as district heating and cooling and large-scale air-conditioning for office buildings, universities and airports.

1.3.3 Hydrocarbons

Hydrocarbons are non-toxic refrigerants that have no ozone depleting potential and minimal impact on global warming. Hydrocarbons are not just good for the environment – thanks to their excellent thermodynamic properties, they have equal or better efficiency than HFC or HCFC refrigerants in most applications.

The flammable chemical properties of hydrocarbons are well understood and managed in different applications. More than 700 million hydrocarbon-based domestic refrigerated appliances worldwide are proving that hydrocarbons can be safely used. The safety of hydrocarbons (as well as other refrigerants) is governed by international, regional and national standards. Many of these, however, restrict the safe use of hydrocarbons and need to be updated to take into account the technological progress that has been made.

Key applications

Typical applications for hydrocarbons include self-contained residential and light commercial equipment, such as domestic refrigerators and freezers, air-conditioners and dehumidifiers as well as stand-alone light commercial refrigerators, bottle coolers, ice cream freezers, beverage dispensers and beer coolers.

In addition, hydrocarbons are used in supermarket refrigeration in combination with secondary cooling or as a high temperature stage in a cascade CO₂ system. Today more than 700 million domestic fridges utilise propane as a refrigerant worldwide, with Europe being 100% converted to this refrigerant in new equipment. Over two million HFC-free units are used in light commercial refrigeration in Europe, most of which use hydrocarbons.

1.3.4 Water

Water is one of the oldest refrigerants used for refrigeration applications. It is an environmentally safe refrigerant with zero ozone depleting potential and zero global warming potential. It is odourless, colourless, nontoxic, nonflammable, non-explosive, easily available, and it is one of the cheapest refrigerants.

Key applications

In refrigeration applications, the use of water as a refrigerant has been mostly limited to absorption and adsorption systems that can be driven by heat sources such as solar thermal, biomass or industrial waste heat, which provides additional environmental and economic benefits as compared to electric driven machines. Water as a refrigerant can provide cooling for buildings, such as universities, offices and data centres.

1.3.4 Air

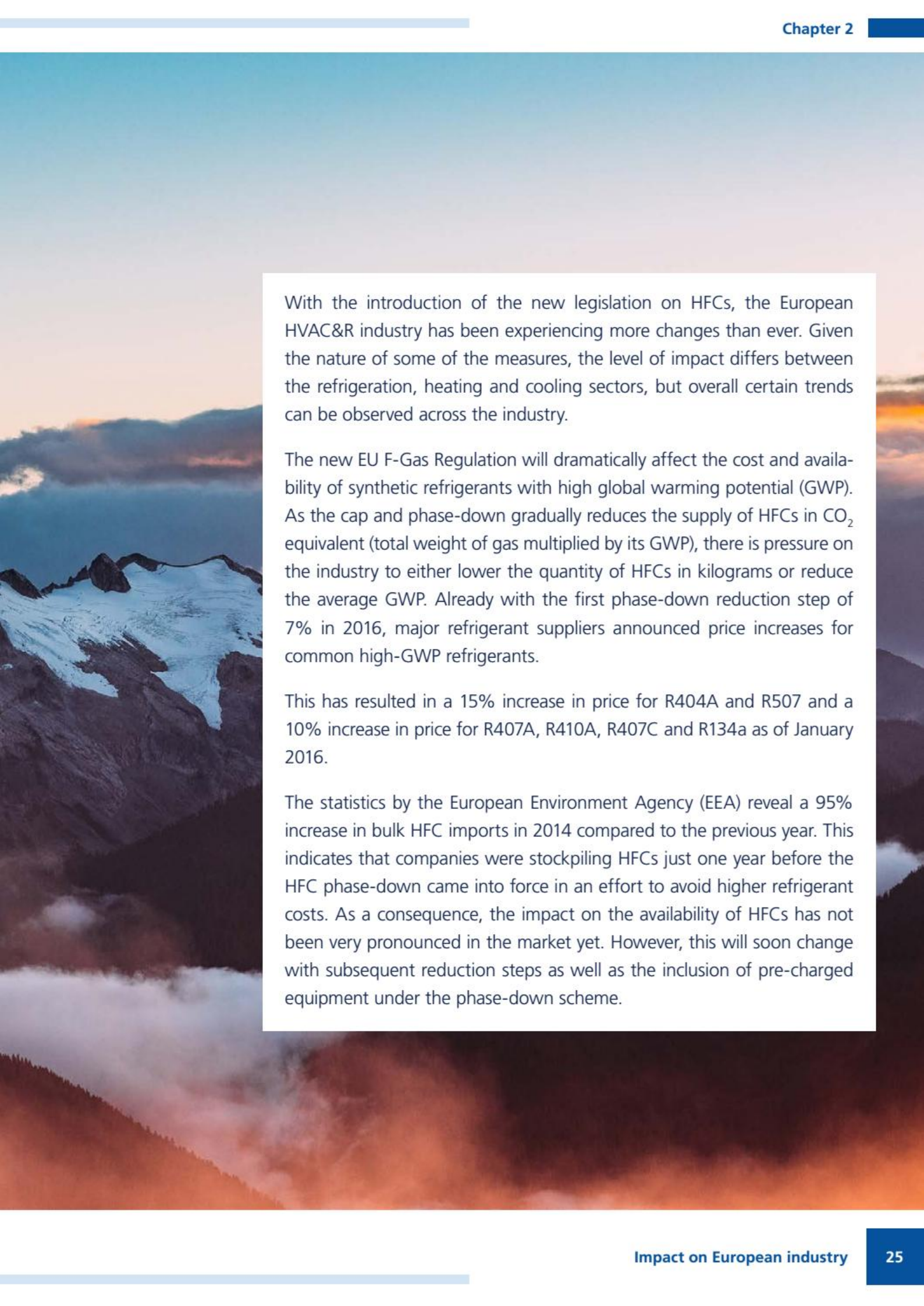
Air is a refrigerant that is environmentally benign, cheap, totally safe and non-toxic. Environmental concerns about ozone depletion, global warming, and increasingly stringent legislation have renewed interest in alternative refrigeration technology globally. However, the use of air-cycle refrigeration systems is not new.

Key applications

Air as a refrigerant was used on refrigerated cargo ships around the turn of the 20th Century. Today, at least 54 units using air as a refrigerant have been installed in Japan and other Asian countries in a number of applications, including chemical process cooling, ultra-low temperature warehouses, and rapid freezing. Systems using air as a refrigerant have not yet been commercialised in Europe.

CHAPTER 2

IMPACT ON EUROPEAN INDUSTRY



With the introduction of the new legislation on HFCs, the European HVAC&R industry has been experiencing more changes than ever. Given the nature of some of the measures, the level of impact differs between the refrigeration, heating and cooling sectors, but overall certain trends can be observed across the industry.

The new EU F-Gas Regulation will dramatically affect the cost and availability of synthetic refrigerants with high global warming potential (GWP). As the cap and phase-down gradually reduces the supply of HFCs in CO₂ equivalent (total weight of gas multiplied by its GWP), there is pressure on the industry to either lower the quantity of HFCs in kilograms or reduce the average GWP. Already with the first phase-down reduction step of 7% in 2016, major refrigerant suppliers announced price increases for common high-GWP refrigerants.

This has resulted in a 15% increase in price for R404A and R507 and a 10% increase in price for R407A, R410A, R407C and R134a as of January 2016.

The statistics by the European Environment Agency (EEA) reveal a 95% increase in bulk HFC imports in 2014 compared to the previous year. This indicates that companies were stockpiling HFCs just one year before the HFC phase-down came into force in an effort to avoid higher refrigerant costs. As a consequence, the impact on the availability of HFCs has not been very pronounced in the market yet. However, this will soon change with subsequent reduction steps as well as the inclusion of pre-charged equipment under the phase-down scheme.

2.1 Market for natural refrigerants growing

Today, more than 650 companies work with natural refrigerants in the EU, Norway, Switzerland and Iceland.

Germany, Switzerland, the Netherlands, the United Kingdom and the Nordic countries remain strong key markets for natural refrigerants in the HVAC&R industry. Moreover, Southern European countries are increasingly investing in natural refrigerants.

Companies that were in compliance with the F-Gas Regulation when it entered into force were able to reinforce their competitiveness in Europe and globally.

shecco first collected data about the availability of European-based companies offering products and services related to natural refrigerants in 2013. Since then, this data has been continuously updated in order to provide an overview of the businesses that can support an effective uptake of natural refrigerants within the EU and beyond.

Today, more than 650 companies work with natural refrigerants (compared to 400 identified in 2013). They range from system and component suppliers, designers, engineering and installation companies to organisations specialising in consultancy, marketing and training. In many cases, companies offer a package of services in order to provide an integrated solution within the industry. The map indicates the location of headquarters or the main European office (in case of a multinational company) per company - each organisation is accounted for only once although several offices and manufacturing plants are usually spread throughout Europe.

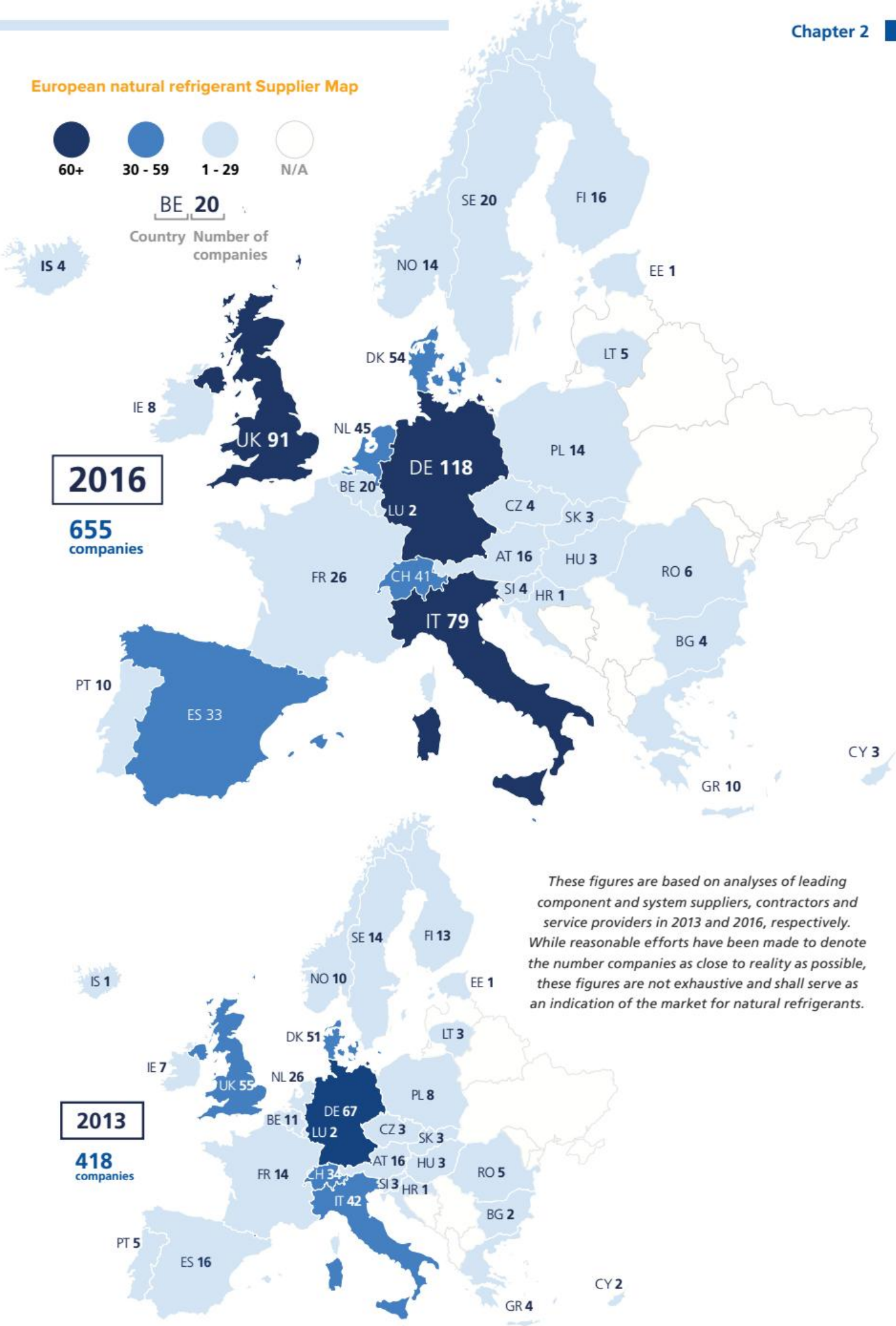
The collected data is depicted on a map that serves as an indicative figure of the main trends in the European market for natural refrigerants. The map captures the status in the EU member states as well as in Norway and Iceland as EEA states that have adopted EU F-Gas Regulation into their national legislation. It also shows the progress in Switzerland as a large number of Swiss companies have become active in the EU as a result of the Regulation.

From this map it emerges that some markets are particularly strong in terms of manufacturing and adopting HFC-free refrigeration technologies. Germany, Switzerland, the Netherlands, the United Kingdom and the Nordic countries remain strong key markets for natural refrigerants in the HVAC&R industry. In

some of these markets, companies were encouraged to switch to HFC-free technologies early on, before the adoption of the F-Gas Regulation, as a result of national regulatory measures limiting the use of HFCs on one side and incentivising the introduction of natural refrigerants on the other. This enabled the companies to benefit from their market position when the Regulation entered into force and continue on this trajectory.

More recent data shows that the trend has spread to surrounding countries as well. Southern countries with warmer climates like Italy and Spain in particular have seen an increase in the number of companies working with natural refrigerants. Some of these markets, such as Italy, have traditionally been solid in the conventional HVAC&R industry. Nevertheless, there are strong indications that many of the existing suppliers within the industry have turned towards environmentally friendly technologies and added them to their companies' portfolios.

Overall, the number of companies working with natural refrigerants has been steadily on the rise. This highlights their function as a sustainable solution for the HVAC&R industry in times when climate-damaging substances are being phased down. In addition to the companies already working with natural refrigerants, numerous others are currently at the crossroads as to which refrigerant to adopt to comply with the requirements. The Regulation has given a push to European businesses to switch to HFC-free technologies and the trend is expected to intensify as the limits on HFCs become more stringent for a variety of sectors. With more suppliers competing in the market, technologies are optimised and thereby become increasingly efficient and available to the end user.



2.2 Overall impact of the F-Gas Regulation

2.2.1 The level of ambition corresponds with industry expectations

Two-thirds of respondents support the F-Gas Regulation's targets; one out of five wants more ambition.

The findings of the survey show that half of the respondents believe the level of ambition of the F-Gas Regulation is appropriate. Overall more than two-thirds of the industry experts expressed their support for the current legislative requirements. 20% of the respondents specified they would like to see more ambitious measures introduced, while close to 30% noted the new rules could pose some challenges. The feedback of individual companies depends on the sector they operate in as well as how well they were prepared to take action to reduce their reliance on HFCs, for example through the introduction or provision of technologies using natural refrigerants.

2.2.2 Industry took action before new rules became effective

Companies investing in natural refrigerants early on could see an increase in the demand for their products before 2015.

The first-movers who had invested in future-proof HFC-free solutions ahead of the EU-wide regulatory changes were able to reap the benefits of their competitive advantage already before the Regulation came into effect.

The survey clearly shows that the industry anticipated the legislative change before the new requirements entered into force. Almost three-quarters of the respondents indicated that they started taking action to comply with the Regulation before its entry into force in 2015. With the legislative process for reviewing the Regulation starting in 2012 and the adoption of the Regulation occurring in April 2014, the industry had some leeway to prepare for the change in the regulatory environment and plan their investments appropriately.

Industry viewpoint:

"We had anticipated that demand would rise with the introduction of the F-Gas Regulation on 1 January 2015. But the level of interest [in CO2 technology] was significantly higher than we had forecast, and when we could not keep up it affected our customers. As a result of the investment in production we can now live up to our promised delivery times."

Micael Antonsson, marketing manager, Green & Cool

"Legislation [like the F-Gas Regulation] will not affect us negatively, as we have been prepared for a while and all our partners in refrigerants are already aware. There will be no business disruption for us."

Antoine Azar, global programme director, The Coca-Cola Company

"[With F-Gas Regulation phase down on the horizon,] we're already adjusting in 2016. We're creating the culture. And people are appreciating it very much. We're also seeing some of our competitors starting to be prepared for these new solutions."

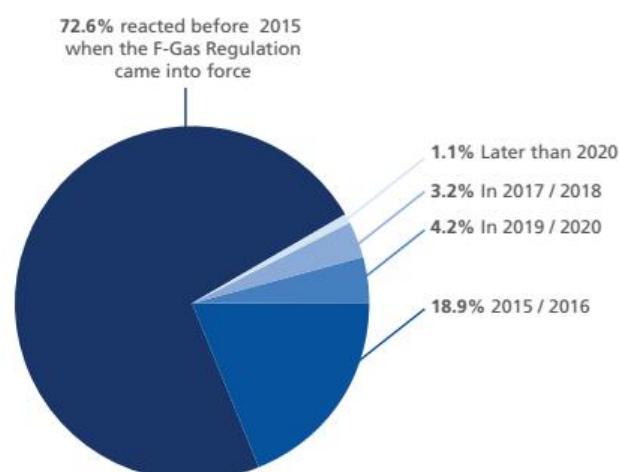
Debora Screpanti, marketing manager, Blupura

The first-movers who had invested in future-proof HFC-free solutions ahead of the EU-wide regulatory changes were able to reap the benefits of their competitive advantage already before the Regulation came into effect. An example of a Danish company working with natural refrigerants in the commercial refrigeration sector demonstrates how the F-Gas Regulation has helped to grow their business not only throughout the EU but also in overseas markets. The company started as a small business primarily in response to the strict regulatory measures introduced in Denmark already in 2001. At the beginning, its activities focused mostly on the local market, but with the anticipation of the new F-Gas Regulation requests for natural refrigerant projects started coming in from all over Europe. Nowadays, the company is active throughout the EU, including South and the East and is one of the major manufacturers of cutting-edge natural refrigerant-based systems for supermarkets. Moreover, it has attracted attention of in the overseas markets when it was acquired by a large US-based corporation which wanted to stay ahead of the competition and introduce the latest technology in North America.

Three-quarters of industry reacted to the F-Gas Regulation before its adoption

Well over half of the industry experts noted they have taken measures beyond the F-Gas Regulation requirements. This is an indication that the industry is able to transform their business and switch to cost-effective and energy-efficient technologies once they have a political signal that such action is rewarded and they are able to benefit from the competitive advantage in the short to medium-term.

While most companies prepared for the F-Gas Regulation beforehand, some 20% indicated that they began to consider taking steps to comply with its requirements in 2015-2016. A small share of the industry does not anticipate taking action before 2017-2018 (3.2%), or 2019-2020 (4.2%), and some will even wait beyond 2020 before the Regulation affects them (1.1%).



Industry viewpoint:

"Pressure from the EU F-Gas Regulation and a Spanish tax penalising the use of fluorinated gases are encouraging the use of alternatives."

José Francisco Mollá, technical director, Carrefour Spain

"The EU F-Gas Regulation of 2015 helped us enormously as it provided a clear direction of what we have to do."

Michel de Rooij, sr. manger technology & process innovation, Ahold

"In recent years the Emerald line has become one of the key products for SCM Frigo. The market is responding very well due to the F-Gas Regulation which is increasing the interest of installers and end users in natural refrigerants, even in countries where natural refrigerant products have not been considered as an alternative so far."

Nicola Pignatelli, sales director, SCM Frigo

"It's evident that the F-Gas Regulation has increased – and will continue to increase – pressure on industry to use CO2 and other natural refrigerants, such as hydrocarbons and ammonia."

Alessandro Greggio, group head of marketing – retail & refrigeration, CAREL Industries S.p.A

Asked to describe the effect of the EU's F-Gas Regulation on the market, Akira Ogushi, sales director at Hoshizaki, argues that regulations alone are not enough to change people's way of thinking. *"There are still a very limited number of customers who have a special request for natural refrigerants. The majority, like small restaurants and pizzerias, are not very much taking care of that."*

2.2.3 HFC bans driving industry to future-proof solutions

The HFC phase-down is the most significant game-changer for the HVAC&R industry. However, there is a risk that the phase-down will not trigger a move to future-proof HFC-free solutions, especially in sectors with no clear HFC bans.

Findings indicate that HFC bans are the most effective measure driving the industry towards long-term technologies, avoiding intermediary and costly steps.

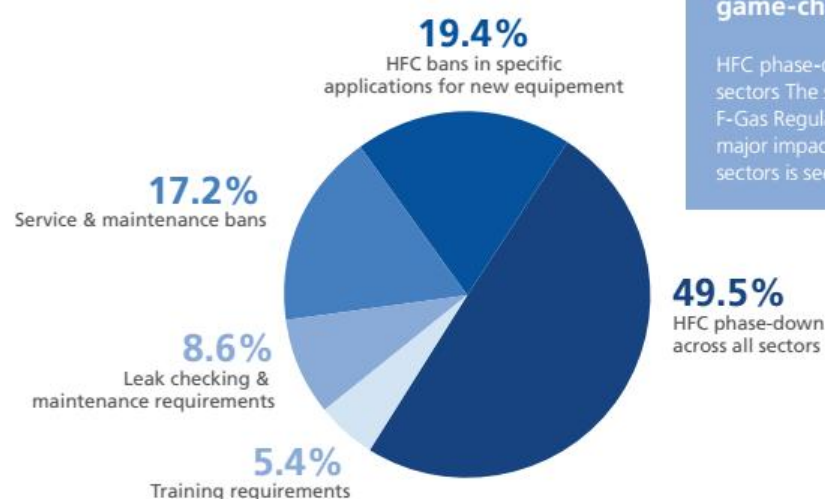
Considering the impact of individual measures adopted under the F-Gas Regulation, overall, respondents rated the HFC phase-down to be the most significant game-changer for the industry. The phase-down will indeed affect the whole HVAC&R sector as it will reduce the availability and increase the cost of HFCs. However, it does not give sufficient clarity to the industry where they need to focus their technology development. The effects of the phase-down might become more evident as further reductions are implemented in the coming years. The inclusion of HFCs contained in pre-charged equipment under the phase-down is also expected to trigger an increase in the price of HFCs, which will have an effect on the adoption of HFC-free technologies.

On one side the HFC phase-down will give an advantage to those that have already developed (or are developing) technologies that do not rely on HFCs, as the price increases will not affect them. On the other side, some company representatives argue that the phase-down will, in reality, not reduce the use

of HFCs in terms of quantity – while overall the average will have to be reduced, the use of refrigerants with lower GWP will be still possible with the same quantities or even higher. There is thus a risk that the phase-down will trigger a shift towards a new generation of HFCs or HFC blends, rather than the future-proof HFC-free technologies, especially in sectors such as heat pumps and air-conditioning where the F-Gas Regulation has not prohibited the use of HFCs. The effects of the HFC phase-down on the industry are therefore not possible to wholly evaluate from today's perspective.

HFC prohibitions in specific applications are **seen as the most effective measure to drive the adoption of natural refrigerants** (instead of intermediary lower-GWP HFCs) and it was rated as the second most important measure overall for shifting the industry away from high-GWP HFCs. Unlike the phase-down, the market prohibitions are sector-specific and affect only specific applications (domestic refrigeration, commercial refrigeration, moveable air-conditioning, small self-contained air-conditioning). HFC bans provide a clear indication to companies as to which technology they need to invest in. Provided the GWP targets are ambitious enough (lower than 150), they noticeably push the market away from HFCs. With a clear deadline and indication of what kind of technology will not be allowed in the market, companies can make timely investment decisions.

Other measures, such as service and maintenance bans, leak checking & maintenance requirements, and training requirements were also noted to have an important role in transitioning away from high-GWP HFCs.



HFC phase-down seen as a game-changer across all sectors

HFC phase-down seen as a game-changer across all sectors. The survey asked industry experts which of the F-Gas Regulation measures they believe will have the major impact on the industry. HFC phase-down across all sectors is seen as the most important game-changer.

2.3 Key aspects the F-Gas Regulation is influencing

While the market for HFC-based equipment is facing increasingly tough restrictions in Europe, technologies using HFC-free refrigerants are gaining popularity. For a number of sectors, especially where bans on the use of HFCs apply, the availability of natural refrigerant-based products has seen an increase across Europe. This in turn reduces the cost of equipment as a result of increased economies of scale, making the new cutting-edge technology competitive with the traditional HFC systems.

With the legislative requirements regarding HFCs, the industry has been intensifying investments in research and development. In addition, a large number of products have been able to surpass the R&D phase and were introduced to the commercial market.

Besides the implications on availability, cost of equipment and technological developments related to HFC-free technology, the F-Gas Regulation has also triggered a change in the training of technicians and a shift in employment towards more sustainable technologies.

In addition, a number of European companies were able to increase their competitiveness in global markets at times when other countries and regions are looking at reducing emissions of HFCs.



Main factors influenced by the F-Gas Regulation

It is important to note that the **level of impact differs from sector to sector and it appears to be more noticeable**

in those sectors where the F-Gas Regulation has introduced a ban on HFCs with GWP > 150, such as supermarket refrigeration.

The survey that shecco conducted among industry experts investigated how a number of these aspects have changed over the last five years in a sector that the respondents were most familiar with. This time horizon gives an indication of the situation before and after the adoption of the F-Gas Regulation. Of 133 respondents to this question, 40% indicated that their companies are most involved in the commercial refrigeration sector, while close to 20% suggested they are most active in industrial refrigeration. The air-conditioning and heat pump sectors were identified as the core activity sectors for 19% and 9% of respondents, respectively. Other HVAC&R areas were not sufficiently represented, which is why they are not considered in the analysis.

Close to 70% of the respondents indicated that they use natural refrigerants in the selected sector, while around 35% said that they use synthetic low-GWP refrigerants with GWP < 150. Overall, the survey demonstrates that around three-quarters of industry already works (to a certain extent) with low-GWP refrigerants that are in compliance with the F-Gas Regulation in their main area of activity. This shows that the industry is already in the process of transformation and businesses are taking their current and future regulatory compliance very seriously.

2.3.1 Availability of technology using natural refrigerants

All companies active in the commercial refrigeration sector have seen an increase in the availability of equipment using natural refrigerants over the last five years, with three-quarters indicating strong growth in this field.

According to the survey findings, all companies active in the commercial refrigeration sector have seen an increase in the availability of equipment using natural refrigerants over the last five years, while 75% indicated that the growth has been strong.

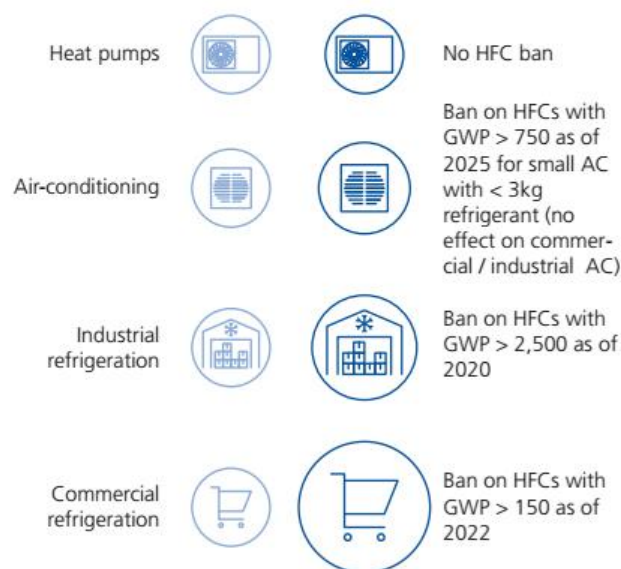
Supermarket refrigeration is an example of a sector where the F-Gas Regulation has had a very prominent impact. This is due to a provision introducing a ban on the use of HFCs with a GWP higher than 150 as of January 2022 in “multipack centralised refrigeration systems for commercial use with a rated capacity of 40 kW...except in primary refrigerant circuit of cascade systems where fluorinated greenhouse gases with a GWP of less than 1,500 may be used”. The European Commission introduced the HFC prohibition following a thorough evaluation, which found that energy-efficient, cost-effective and technically viable alternatives to high-GWP HFCs in this sector are available.

The F-Gas Regulation has further accelerated the shift to natural refrigerants in the commercial refrigeration sector, which is strong evidence indicating that HFC bans are the most effective measure in transitioning away from HFCs.

As for the industrial refrigeration sector, 65% of respondents have seen either a slight or strong increase in commercial availability of new products using natural refrigerants over the last five years, while the rest indicated that there has been no major change in this sector. Ammonia is in fact already the standard refrigerant in large industrial refrigeration so this sector has, to a large extent, already shifted to future-proof technology without any regulatory intervention. Nevertheless, there is growing competition for ammonia in this segment from other solutions using natural refrigerants, including CO₂/ammonia cascade and secondary systems, as well as CO₂ transcritical technology⁵. For example, the biggest CO₂ industrial refrigeration project in the world will soon (January 2017) start operation in a lettuce processing plant in the Netherlands.

Besides the large installations, growth in availability of HFC-free solutions is occurring also in small and medium-sized industrial refrigeration sites where HFCs have so far been dominant.

According to the industry representatives, **the increase in new HFC-free products in the sector of air-conditioning and heat pumps is not very pronounced** and only a few experts indicated that there has been a slight increase in product offerings, while a majority stated there has not yet been a major market shift. This could be explained by the fact that while bans on HFCs with low GWP (< 150) are not foreseen in this sector (except for movable AC), the effects of the HFC phase-down will only kick in within the next few years when HFCs with high GWP become more scarce.



5 YEARS AGO

TODAY

Availability of natural refrigerants is growing for refrigeration sectors

F-Gas Regulation gives boost to naturals in food retail

The number of CO₂ transcritical stores in the EU, Norway and Switzerland has tripled over the past three years, reaching 8% of the overall market share in the food retail sector.

Besides established markets in Western and Northern Europe, CO₂ transcritical technology has grown in the south and east as well.

In order to illustrate the transition of the commercial sector towards natural refrigerants, shecco conducted a survey among refrigeration system suppliers and retailers in Europe. The gathered data is an update of a market study done by shecco in 2013, so as to compare the changes in the recent past and to assess how extensive the impact of the Regulation has been on this sector. **The focus of the investigation lies on transcritical CO₂ refrigeration systems, which this has become the mainstream cutting-edge HFC-free technology for the food retail sector.** It is important to note that other natural refrigerant technologies in commercial refrigeration applications have emerged or become more prominent which satisfy the regulatory requirements of end users, besides CO₂ transcritical technology.

⁵ The transcritical cycle is a thermodynamic cycle where the CO₂ passes through a state, in which it is no longer a liquid or a gas.

The map of *Stores using cutting-edge HFC-free technology in Europe* depicts the number of supermarkets per country that use CO₂ transcritical refrigeration systems in 2016 compared to 2013. Besides the EU member states, the map indicates the developments in Norway and Switzerland where a large number of installations have been done by EU companies as a result of their increased competitiveness in these markets. With a growing number of suppliers and end users adopting the technology, the collected data might not fully capture the whole market, but it serves as a strong indicative figure of the main trends in commercial refrigeration with natural refrigerants.

The map shows that, overall, **the number of stores using CO₂ transcritical systems has tripled over the past three years**. Today, **at least 8,732 food retail stores in Europe have such systems installed**. With an overall market size of about 110,000-115,000 supermarkets, this represents around 8% of the European grocery sector. The overall market size of supermarkets takes into account food retail stores in the European Union, Norway and Switzerland that are bigger than 400m², as those are the ones that are primarily installing CO₂ technologies. There are strong indications that the technology will soon penetrate into small format stores with a growing number of natural refrigerant-based solutions becoming available for this segment.

From a regional perspective, Germany, Switzerland, the United Kingdom and the Nordic countries were traditionally strong in developing and adopting systems based on natural refrigerants. These countries have continued their trajectory and further accelerated the installation of new systems in the last three years.

However, it is important to note that the most recent market findings show growth in CO₂ transcritical installations in other regions besides the already established markets in Western and Northern Europe. At the time of the adoption of the F-Gas Regulation some members of the industry argued that CO₂ technology is not a viable solution for the warmer climates of Southern Europe. However, the findings indicate that **the industry was able to overcome the technical challenges and barriers related to lack of awareness** as a growing number of CO₂ stores have been emerging in countries like Spain, Italy, Romania, and the south of France.

Furthermore, eastern European countries are slowly starting to embrace natural refrigerants. Latvia and Lithuania adopted these technologies for the first time between 2013 and 2016.

Industry viewpoint:

"With the revised EU F-Gas Regulation in effect from 2015 onwards, we expect an accelerated move towards CO₂ in supermarket refrigeration (but not the entire commercial refrigeration segment) within the next five years. It is likely that two-thirds of the commercial refrigeration segment will be using CO₂ with the remaining one-third covered by HFCs or HFO blends."

Christoph Brouwers, director turnkey operations, Carrier Commercial Refrigeration

"At Carrefour, we would like to go straight to a final solution. By using CO₂ or other natural refrigerants, we are also avoiding [the risk] that in two or three years' time, there may be another update of the F-Gas Regulation, limiting other gases and decreasing even more the GWP."

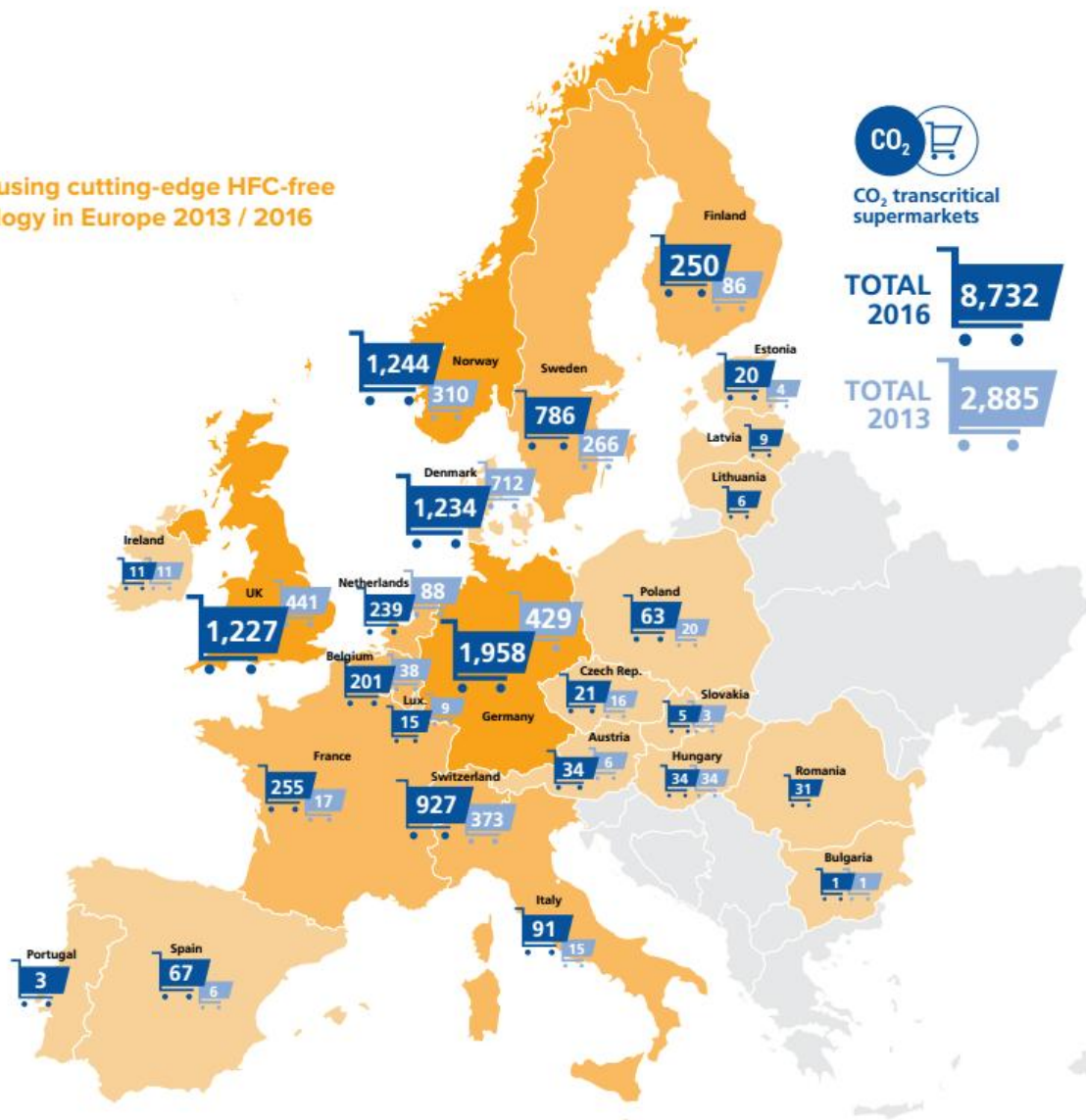
Paolo Martini, refrigeration & HVAC manager for international support, Carrefour Group

Annual growth indicates early action

Europe-wide, an increase in installations per year has been observed. The data only includes new CO₂ system installations until July 2016 and, therefore, the estimated number for 2016 would be well above 2,200. Even though the F-Gas Regulation only took effect from January 2015 onwards, the necessity for the commercial refrigeration sector to shift to environmentally friendly refrigerants became clear much earlier. In November 2012, when the European Commission published their proposal for revising the Regulation on fluorinated greenhouse gases, signals were sent out to the industry that legislative changes were to come. Even then indications were strong that the commercial refrigeration sector would be affected due to the recent advancements in low-GWP technologies that had been made.

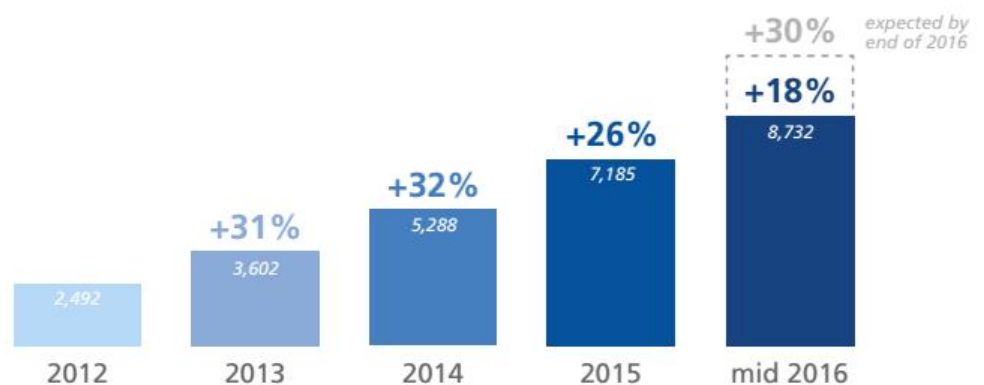
As such, the market started quickly shifting towards natural refrigerants with the pace increasing in recent years. The overall increase in installations of CO₂ transcritical refrigeration systems is remarkable and only expected to translate into a continued exponential trajectory in the future. Industry representatives working with CO₂ technology predict that as of 2018 there will be approximately 6,000 new CO₂ transcritical stores opened annually.

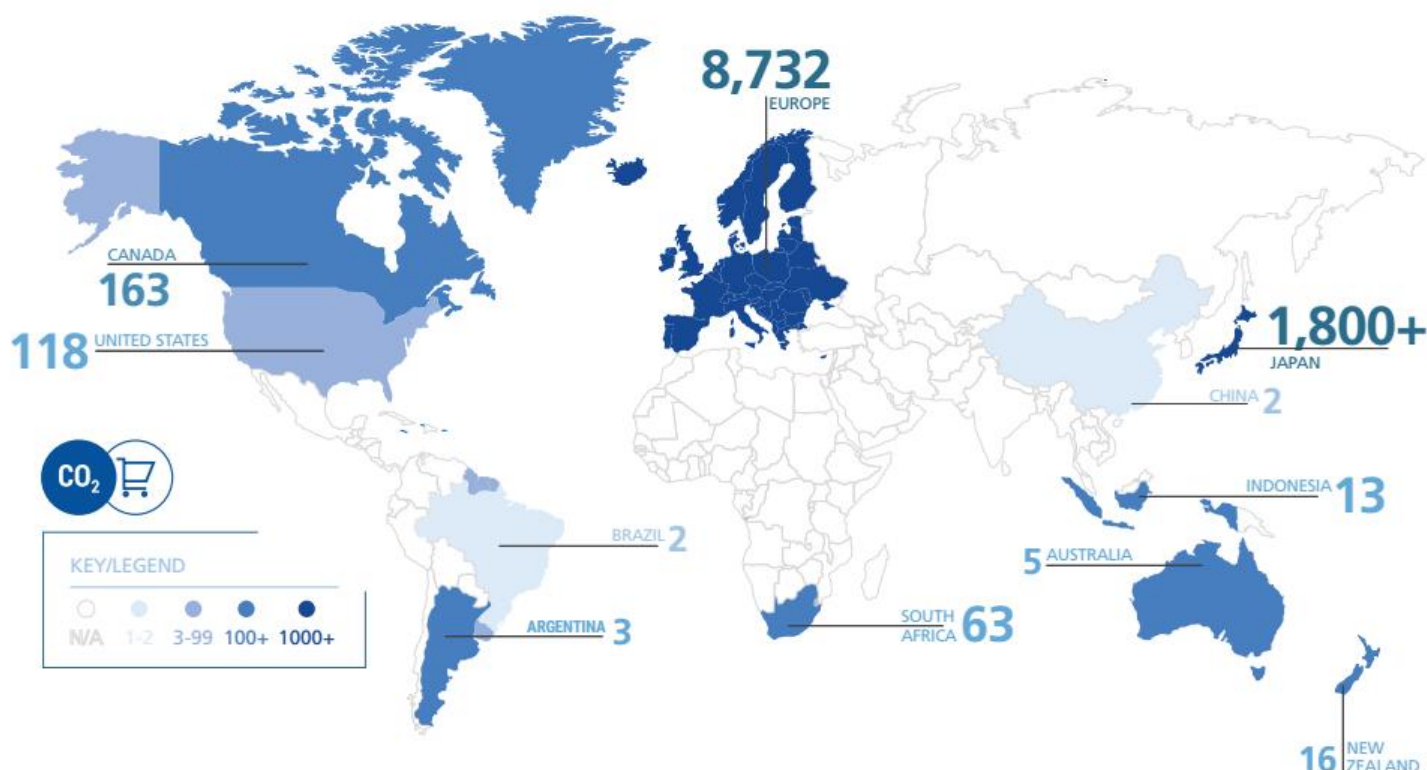
Stores using cutting-edge HFC-free technology in Europe 2013 / 2016



These figures are based on a 2016 survey of leading system suppliers and commercial end-users. The map depicts the number of stores using CO₂ transcritical technology, which has become the mainstream cutting-edge HFC-free technology in Europe. Besides CO₂ transcritical systems different other types of HFC-free equipment are becoming popular in the food retail sector.

Growth of CO₂-based stores in Europe



CO₂ stores in global perspective

The use of CO₂ transcritical systems is growing globally. The map shows that from east to west, north to south, that there is a market for CO₂ transcritical technology. The greatest proliferation is in Europe but the last two years has seen great growth worldwide, particularly in North America, South Africa and Japan.

**Canada: 163**

Canada leads the charge in North America, benefiting from CO₂ transcritical's excellent efficiency in low-ambient temperatures. Sobeys is the most proactive supermarket in installing CO₂ systems, currently with 82 stores equipped with CO₂ transcritical technology. Sobeys transition was accelerated in Quebec by subsidies provided by Quebec's OPTER programme.

**Japan: 1,800+**

Japan is one of the largest markets in terms of refrigeration with natural refrigerants. There are more than 1,800 supermarkets that use CO₂ transcritical technology, a number that is expected to grow to 2,000 by the end of 2016. This development is mainly thanks to the subsidy scheme of the Japanese Ministry of Environment (MOE) that took active steps to combat rising HFC emissions. From 2014 onwards, the MOE has provided a significant budget to incentivise the use of natural refrigerants in food refrigeration systems and showcases.

**United States: 118**

The United States has improved its usage of CO₂ supermarkets with an increase from two installations in 2013 to 118 in 2016. While the United States may be behind in terms of the total number of transcritical stores, they are at the forefront of technological advancements with innovative CO₂ installations in warm-ambient climates.

**South Africa: 63**

South Africa is seeing increased usage of CO₂ transcritical systems, with retailers Woolworths and Makro using the systems in their supermarkets. As the market for CO₂ technology grows globally, system suppliers in South Africa are confident that this market will continue to prosper.

**China: 2**

China's commercial refrigeration sector is still in its infancy, with two CO₂ transcritical stores. There is, however, an expectation that this will grow soon with international supermarkets, such as Carrefour and Metro, looking to increase penetration of CO₂ technologies in China.

2.3.2 Technology innovation

More than four in five companies that are active in the commercial refrigeration sector have increased their R&D investments in natural refrigerant technologies in the last five years.

Companies active in the heat pump and AC sectors have also augmented their R&D focus on natural refrigerants, indicating more products should become available in the short- to medium-term.

The F-Gas Regulation has been a strong driving force for technological innovations across different HVAC&R sectors. Industry representatives have indicated that their R&D investments in technologies that do not rely on HFCs or use low-GWP synthetic alternatives (GWP < 150) have increased over the last five years, not only in the refrigeration sector, but also in the sectors of air-conditioning and heat pumps. This shows that more low-GWP products should become available within the next few years once the effects of the Regulation become more amplified.

When asked how much the R&D investments for natural refrigerants have grown in different sectors, 83% of respondents active in commercial refrigeration have seen an increase over the last five years; with 53% indicating the growth has been particularly strong. Companies active in other sectors have not been lagging behind in this respect, with close to 60%, 50% and 33% indicating a growth in channeling the investments towards natural refrigerant-based technologies in industrial refrigeration, heat pumps and air-conditioning respectively.

Indeed a great deal of innovation has been occurring in the industry, with a clear focus on advancing the development of technologies that are future-proof in terms of regulatory compliance.

Technology advancements for small stores

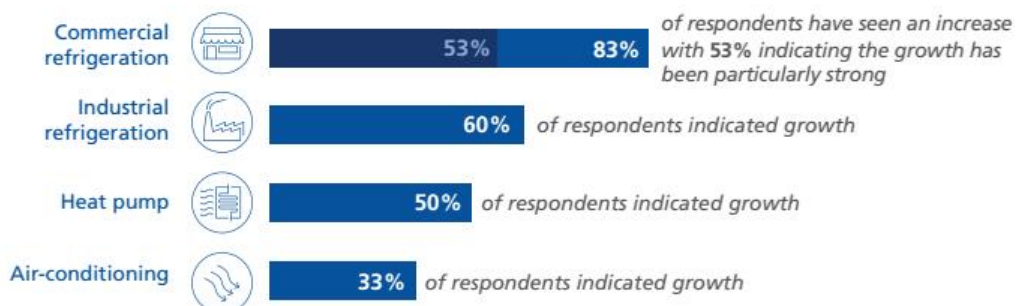
As the standard CO₂ transcritical technology for supermarkets has matured, the focus of technological innovation has shifted to the development of optimal solutions for small format stores and warmer ambient climates.

As the standard CO₂ transcritical technology for supermarkets has matured, the focus of technological innovation has shifted to the development of optimal solutions for small format stores and warmer ambient climates.

At the time of the F-Gas Regulation's adoption, it was argued that retailers operating small stores would not be able to comply with a ban on HFCs with GWP < 150. This is a reason why a compromise had been reached to exclude small stores from the prohibition that now only applies to supermarket systems with a capacity of more than 40kW. Nevertheless, with the evolution and maturing of the CO₂-based technology in medium- to large supermarkets, the focus of the technological innovation has shifted to development of optimal HFC-free solutions for smaller stores.

CO₂ condensing units, which are typical in smaller stores, have been introduced by a number of companies. More should be commercialised in the near future. The technology for convenience stores has seen strong growth in Japan and amid confirmed interest from European end users, companies like Sanden and Panasonic are adapting the technology and introducing it in the European market. Moreover, a number of European companies have launched products for small stores.

Significant increase in R&D investments in natural refrigerants over the last 5 years



In April 2016, Green & Cool unveiled its small stand-alone condensing unit that utilises CO₂. The company believes that the condensing unit will work in ambient temperatures of up to 45°C, making it suitable for use in warmer climates like Southern Europe. With demand for the units already high, the product will now undergo field tests in Sweden and England. The first units are expected to go on sale at the end of 2016.

Advansor is another company that has developed a CO₂ condensing unit – the compSUPER XXS – targeting small store formats. Energy savings of 20% can be achieved when comparing a compSUPER XXS unit from Advansor to a traditional HFC condensing unit. These savings are achieved through better evaporator regulation and a frequency-controlled compressor.

Other natural refrigerant technologies are being developed and improved for small format stores. Hydrocarbons are seen as a very suitable option for responding to the F-Gas Regulation, as they are “simple and flexible” for retailers who are already familiar with HFC-based plug n’ play systems.

European businesses tackling the ‘CO₂ equator’ line⁷

The F-Gas Regulation has triggered innovation in technologies for warmer ambient regions, with a number of companies introducing HFC-free solutions that have proven to work efficiently in temperatures of up to 45°C.

It was previously considered that the southern European countries would face difficulties in meeting the 2022 HFC ban for commercial refrigeration due to their warm ambient climates. This was due to the fact that CO₂-based technologies had been believed not to be able to reach efficiency levels of conventional HFC systems.

The F-Gas Regulation has indeed triggered innovation in this area, with a number of companies investing into the development of HFC-free solutions to cater to retailers in Southern Europe. Back in 2013, the so-called ‘CO₂ equator’ line was believed to be running through Southern Europe along the northern shore of the Mediterranean. Today, as a result, high-efficiency solutions exist that are capable of transcending this line. These include parallel compression⁸, adiabatic cooling⁹, ejectors¹⁰ and sub-coolers¹¹. It is believed that the use of parallel compression and ejector technology will significantly improve the perfor-

mance of CO₂ transcritical systems, which have already proven to be more energy-efficient than conventional HFC-based systems. According to Armin Hafner, professor at the Norwegian University of Science and Technology, it has been reported by several experts that the efficiency of R744 ejectors is generally in the range of 20-30% at elevated ambient temperatures.

Component manufacturers will soon be ready to deliver serial production parts to the market: this is a major step forward for the large-scale introduction of centralised commercial refrigeration systems in Southern Europe.

Most recently, two major HVAC&R companies CAREL and Carrier Commercial Refrigeration have joined forces to develop and industrialise a range of modulating ejectors to improve energy efficiency of CO₂ refrigeration in Southern Europe. At the ATMOSphere Europe conference in March 2016, where the technology was officially launched, Diego Malimpensa of CAREL said: “We’re now moving from concepts to real industrial sustainability solutions.” Presenting a new series of adjustable CO₂ ejectors for commercial refrigeration systems, Sascha Hellmann – project leader for systems development at Carrier Commercial Refrigeration – said that the company’s transcritical CO₂ system with the CO₂OLtec ejector rack was capable of reducing the average energy consumption of a total refrigeration system by 13%.

In April 2016, Italian retailer Iper opened a grocery store in Milan that uses a CO₂ refrigeration system with ejector technology to enhance efficiency in temperatures of up to 38°C, demonstrating that CO₂ refrigeration is advancing across Southern Europe as an efficient and viable solution. Since it was only commissioned in April 2016, it is still too early to provide figures for the actual energy savings of the Milan hypermarket. However, the experience of Danfoss (which took part in system design, testing of packs and commissioning) from similar installations with heat recovery, intelligent control and ejector technology points to energy savings of up to 50% compared to more conventional installations.

Carrefour has installed CO₂ transcritical systems in 18 hypermarkets and one supermarket. While there were performance challenges with the first installation, these were eliminated through constant developments and close collaboration with the technology manufacturers. Integrating several elements, such as parallel compression, sub-coolers and ejectors, solved the performance challenges in high ambient temperatures. **The results show an impressive 45% energy efficiency savings on average from refrigeration systems alone, in comparison to the standard HFC installations previously in place.**

⁷ The previously accepted geographical limit in which using a CO₂ system would no longer be cost-effective due to the warm climate

⁸ A process in which the gaseous refrigerant is removed at a high pressure in order to reduce energy consumption

⁹ Adiabatic cooling is based on the principle that evaporating water removes heat from its surroundings, used in water-scarce areas with warm climates to reduce water use while still reducing heat in the system

¹⁰ Ejectors work by converting internal energy and pressure-related flow into kinetic energy

¹¹ Sub-coolers keep the refrigerant in liquid form so that it may undergo the remaining stages of the refrigeration cycle

A CO₂ installation at a Carrefour supermarket in Madrid with mechanical sub-cooler reached a better energy performance (COP of 2.0) or higher compared to the best in class R448A DX system in temperatures up to 40°C. Another installation was made at a small Italian supermarket chain (Orvea) last year, which worked at 45°C last summer.

Developments to further improve energy efficiency of CO₂ transcritical systems are on-going and results today are already showing that the technology can perform better than conventional systems based on HFCs.

Integrating heating, cooling and refrigeration into one system will bring substantial additional energy efficiency benefits, which can only be achieved with CO₂ due to its specific characteristics. Such systems are already coming to market today and are expected to become more popular before the 2022 ban enters into force.

Industry making progress beyond commercial refrigeration

While much of the innovation has focused on improving HFC-free technology for commercial refrigeration systems (given the imminent HFC ban), there have been significant advancements in developing technologies that do not rely on HFCs in other sectors as well.

Dutch company Unichemie launched a patented natural refrigerant heat pump system using propæne¹² as the refrigerant in 2015. The heat pump is designed for heating and cooling of medium and large buildings. The cutting-edge technology allows for reductions in energy consumption of up to 50% and can bring a building to energy label A+++, the highest attainable level in energy efficiency.

In transport refrigeration, Carrier Transicold Europe launched a prototype of the company's new E-Drive Natural Refrigerant Trailer in 2014. The refrigeration unit is dedicated to road transport and uses CO₂ in a closed loop system. The prototype aims to demonstrate the future for refrigerated transportation systems in compliance with the EU F-Gas Regulation.

2.3.3 Cost of equipment

Industry notes falling prices in commercial refrigeration: total installation price is currently at the level of conventional HFC technology or 5-10% higher, depending on the market and technology.

The upfront cost of equipment using natural refrigerants is often higher in certain sectors, where these refrigerants are not yet the standard technology. However, the overall lifecycle cost is lower than conventional technology that relies on f-gases, thanks to improved energy performance, lower maintenance costs and other factors. With growing production capacities, however, the cost of equipment decreases as more suppliers enter the market and the availability of components increases. This is a basic economic principle that would apply to any other sector and HVAC&R is no exception in this respect.

¹² A hydrocarbon mixture comprised of propane and propylene

Industry viewpoint

"CAREL has invested in solutions that can be used to overcome the limits both already introduced and soon to be introduced by the F-Gas Regulation."

Alessandro Greggio, group head of marketing – retail & refrigeration, CAREL Industries S.p.A

"The CO₂ vending machine is ready now. We just need to decide whether the market is. We know that by 2020 HFCs will have to be phased out in Europe, and we're focusing on developing R744 and R290 systems as alternatives."

Ivo Pancheri, product manager, Fas International Spa

"It is true that CO₂ in industrial applications is not as common as in the commercial sector, after the ban of f-gases by the F-Gas Regulation we will see more industrial installations."

Joachim Dallinger, product & marketing manager, Epta Deutschland

"The F-Gas Regulation and a greater environmental focus from the bigger players in the refrigeration industry will drive natural refrigerants. CO₂ systems today represent almost 70% of SCM Frigo production. We have also developed a new ammonia chiller line to get even closer to our goal to have nature and technology working as one."

Nicola Pignatelli, sales director, SCM Frigo

"Europe knows what is going to happen in the next couple of years, and they are really seeing R290 as a solution."

Nelson Marques, assistant commercial director, Ficon

From the end-user perspective, especially for small and medium-sized businesses and individuals, the 'price tag' is often the decisive factor when purchasing new equipment. It is therefore an important aspect that can determine the success of a technology.

In sectors where natural refrigerants are a standard technology, the cost of equipment is comparable to systems using HFCs. This is the case in domestic refrigeration where hydrocarbons are the standard refrigerant in all new appliances as well as in industrial refrigeration where ammonia is even more cost-competitive than HFCs, especially from a lifecycle point of view.

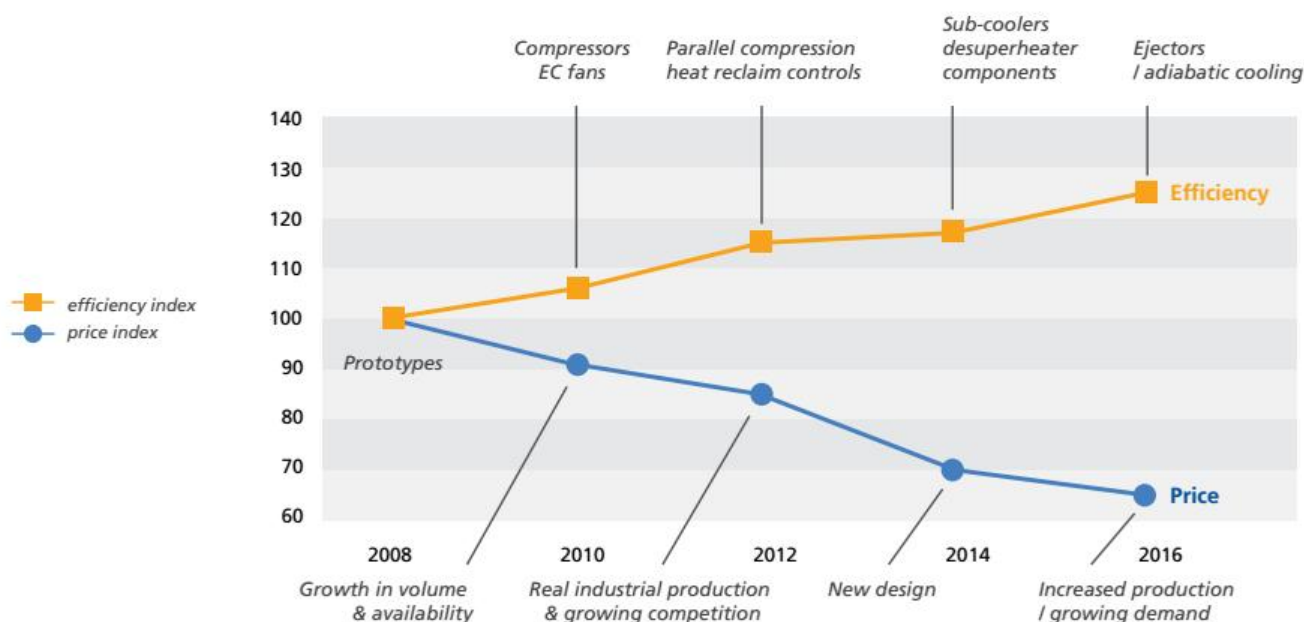
Signs of falling prices of natural refrigerant-based units are now also registered in sectors that have seen a strong growth in this technology, such as commercial refrigeration. Industry representatives confirm that prices of compressor racks went down dramatically because of a steady increase of supply and demand; the cost of CO₂ compressors is now lower than cost of equivalent HFC compressors. Depending on the market and technology, the total installation price is currently 0% or 5-10% higher compared to conventional systems. Paolo Martini, refrigeration & HVAC manager for international support at Carrefour Group, confirms this trend. He notes that the prices are falling as more equipment becomes available. "I think this is a trend, and that we'll get even better prices in future," he says.

"Adopting systems based on natural refrigerants is in fact guided by budget and strategic decisions, rather than solely related to energy efficiency," according to Olaf Schulze, director of energy management at METRO, the largest member of the Metro Group.

With parallel compression and ejectors the CO₂ transcritical technology is suitable for warmer climates (up to 45°C). Although the technology is now more expensive than HFC-based systems in terms of initial cost, this is expected to go down as technology becomes more widespread (as has been proven for the standard CO₂ booster system). Industry experts estimate that with ejector technology and parallel compression, the price of a system is a maximum 10% higher.

Growing efficiency, decreasing prices

It is interesting to take note of the relationship between increasing energy efficiency as a result of technology advancements and dropping cost of equipment, which is due to increasing demand and production volume. The graph below indicates the developments for CO₂ supermarket refrigeration as Advansor, one of the major European suppliers of CO₂-based equipment, has registered them. While the efficiency has increased by 25% between 2008-2016, the cost of equipment has fallen by 30% in the same period.



Source: Advansor, ATMosphere Europe 2016

Industry viewpoint:

Aldi South has decided to solely use CO₂ refrigeration systems for its stores because of the cost savings they can achieve. "The investment and maintenance costs of transcritical CO₂ refrigeration systems can be compared to those of F-gas refrigeration systems. However, the costs for the CO₂ refrigerant are relatively low."

Kirsten Geß, communications director at Aldi South

"Today it is still the refrigerant that answers best to all environmental and energy criteria. What is more, the technology and its components are becoming more affordable and the total cost of installations has decreased considerably over the last few years. The implementation of the F-Gas Regulation wasn't an accelerating element, but rather a confirmation that we took the right options at the right time."

Georgios Patkos, former director of technical department, Delhaize

"Industry is able to develop the technologies and make them cost-efficient, as long as we give the signal [to companies]. Let's not talk about ambition [of F-Gas regulation], but just accept the change."

Sylvain Gillaux, European sales & marketing manager, Sanden

2.3.4 Training and awareness

Out of a total of 160,000 technicians in Europe, 8,000 - 10,000 received training on natural refrigerants in 2015.

The United Kingdom and France emerge as hotspots for natural refrigerant training (in terms of number of training providers), followed by Germany, Spain, Italy and Sweden.

Almost 50% of those that do not provide or receive training on natural refrigerants have plans to get involved in this type of training between 2016-2020.

The current mandatory training and certification for HVAC&R equipment under the F-Gas Regulation addresses only fluorinated refrigerants and does not consider the safe handling of HFC replacements, such as CO₂, ammonia and hydrocarbons. The Regulation only requires certification programmes and training to include "information on relevant technologies to replace or to reduce the use of fluorinated greenhouse gases and their safe handling".

Given an increasing market share of natural refrigerant-based technology in Europe and the growing complexity of components and new system solutions, including electronic modulating ejectors, integrated frequency inverters, electronic components or compressors, the demand and supply of proper training on natural refrigerants is steadily rising.

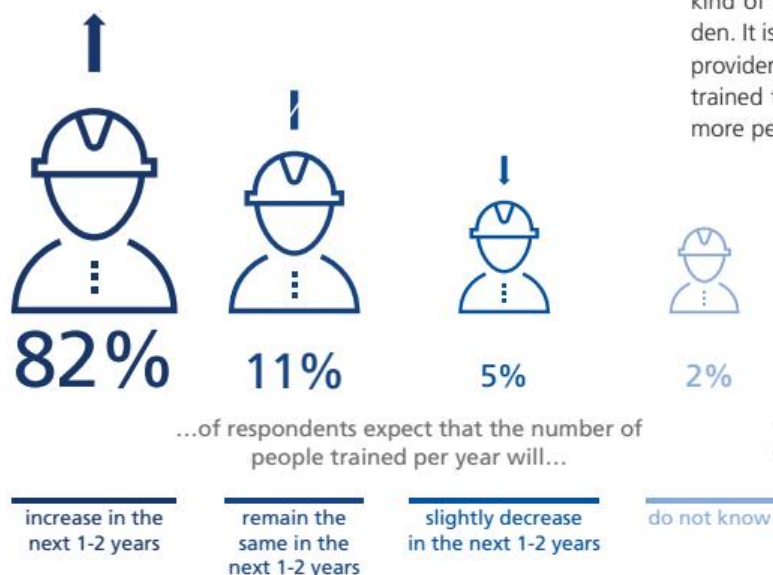
There are roughly 160,000 technicians in 21 EU member states. To get a more comprehensive picture, shecco conducted a survey to ask the industry how many people have been trained on natural refrigerants in 2015. The findings indicate that the number of technicians who received training on natural refrigerants last year is approximately 8,000-10,000. The survey also revealed that the F-Gas Regulation is considered to be the main driving factor for the uptake of natural refrigerants training.

The natural refrigerant training providers have expressed optimism that the number of people trained per year will increase in the near future. Four in five of HVAC&R industry experts expect to see this number increase in the next one to two years. In addition, just over one tenth of natural refrigerant training providers said that the numbers will remain the same.

Moreover, as for future plans to provide or receive natural refrigerant training among those that are not yet involved in this type of training, almost 50% responded that they have plans to either provide or receive such training in the period between 2016-2020.

The availability of training is improving and so are numbers of trained technicians able to handle the equipment. This has been confirmed by major food retailer Carrefour: "With the increased training offer in refrigeration, both from industry, but also from public organisations, we now have a good number of options for training our technicians."

Several companies in Europe are already taking steps to provide training on natural refrigerants. shecco has identified **close to 200 companies in Europe, including training institutes, system and component manufacturers, universities, research institutes, associations and other organisations, who offer training related to natural refrigerants.** The United Kingdom and France appear to be hotspots for this kind of training, followed by Germany, Spain, Italy and Sweden. It is important to note though that the number of training providers does not necessarily correspond with the number of trained technicians by country (one training facility could train more people than others).



Number of people trained on natural refrigerants expected to grow strongly

Training providers most commonly give theoretical training (either on-site or long-distance) and more than three-quarters also offer practical training, which offers the opportunity to get real-life experience with natural refrigerant-based equipment.

Examples of recent training programmes offered by system and component manufacturers include the CO₂OLacademy and SCHAUFLEER Academy. Carrier Commercial Refrigeration opened its CO₂OLacademy to provide field training on CO₂ technology and improve the skills and technical knowledge of Carrier's technicians in Europe.

BITZER's new training centre, the SCHAUFLEER Academy, was officially inaugurated in February 2016. All the academy's refrigerant training sessions cover issues like thermodynamics, safety, material compatibility and system design. Courses on transcritical and subcritical CO₂ systems also offer hands-on training to ensure that participants are equipped with the necessary skills to deal with day-to-day operating demands. Participants also learn how to fill systems up properly or start them up from scratch.

While these are just a few examples of natural refrigerant training programmes, they serve to defend Advansor Managing Director Kim Christensen's argument that: "The story that there isn't enough CO₂ training capacity is a lie." He cited courses at universities in France and Belgium, refrigeration schools in Denmark and Sweden, and training centres run by system and component manufacturers, including Advansor.

Industry viewpoint:

"Due to the EU F-Gas Regulation and the phase-down of HFCs, more and more users will apply natural refrigerants. With a broader customer base, there is a bigger need for training as well. We want to make sure that we don't create potential for failures, because it would have an impact on the market of natural refrigerants."

Rainer Große-Kracht, board of directors, BITZER SE

"In Denmark, the EU F-Gas Regulation does not have a big influence because our national regulation already takes care of this. But generally speaking, the F-Gas Regulation focuses peoples' attention on reducing the use of HFCs, which is especially important outside of Denmark. There will be great opportunities for Danish companies manufacturing components and systems compatible with natural refrigerants to address the European market because this market will grow dramatically. Until now, there have been a limited number of experts who are skilled enough to handle CO₂ systems. This number must increase. And of course, there will be a need for training all over Europe."

Christian Heerup, senior consultant, Danish Technological Institute (DTI)

"A concerted effort is necessary to ensure appropriate training of technical personnel in handling flammable, high pressure or toxic refrigerants. In our experience, the lack of such training is often an argument against natural refrigerant solutions for end users. Large manufacturers have noticed this and have set up their own training facilities. Efforts by industry and associations to establish an EU-wide certification for handling natural refrigerants will pave the way for more trust and a faster uptake of these vital technologies."

Barbara Gschrey & Bastian Zeiger, general manager & project manager, Öko-Recherche

"With the increased training offer in refrigeration, both from industry, but also from public organisations, we now have a good number of options for training our technicians. You can also get training at universities. But we mainly work with industry."

Paolo Martini, refrigeration & HVAC manager for international support, Carrefour Group

CHAPTER 3

IMPACT OF THE EU F-GAS REGULATION BEYOND EUROPE



3.1 EU legislation shaping the global industry

“There is only one reason why our European business is ahead of the rest – and that’s because the [F-Gas] Regulation has moved faster in Europe.” André Fourie, SAB Miller

At the time of its adoption, the EU F-Gas Regulation was the most ambitious and comprehensive piece of legislation addressing the use of fluorinated refrigerants on a supra-national level, which has had a far-reaching impact not only on the EU’s 28 Member States but also other global economies. It is fair to note that even prior to the revised EU Regulation some European countries, such as Denmark, had adopted ambitious measures at national level to combat growing emissions of fluorinated gases.

While the EU F-Gas Regulation is directly affecting businesses with activities in Europe, the legislation has had an impact beyond Europe in a number of ways. The EU’s open trade regime means that the region is the biggest player on the global trading scene and remains a vitally important region to do business with. International companies with an interest in continuing to do business in Europe in the field of heating, cooling and refrigeration have to comply with the new rules. “Through its [F-Gas Regulation] implementation process there have been a number of countries, specifically China, is asking how it’s implemented and how it actually works so they can comply with it when they are exporting to the EU market,” said Philip Owen, head of Climate Finance, Mainstreaming, Montreal Protocol Unit at the European Commission’s Directorate-General Climate Action, who is leading the team responsible for designing and implementing the F-Gas Regulation rules.

A large number of companies operating in this sector are global businesses with activities around the world and the Regulation has had an impact on how they do business and what types of products they offer outside of Europe. As technologies using HFC-free refrigerants become more widely available in Europe, opportunities are created for companies to offer such equipment in other regions.

According to Hugo Blaum, president at GEA Refrigeration Technologies, one of the key global component suppliers for HVAC&R equipment, “as a result of the new F-Gas Regulation, demand will appreciably increase for natural refrigerants and their associated refrigeration systems throughout the rest of the world. European standards for protection of the climate and the environment frequently set the pace for other countries as well.”

“This historical decision [adoption of the EU F-Gas Regulation] is a potential game changer for the industry. It is a signal that policies will lean towards more climate-friendly refrigerants in the future. I believe that this decision will also encourage a market transition to natural refrigerants such as CO₂ and ammonia in China,” said Christian Overgaard, president at Danfoss China, another major international component supplier.

From a perspective of a technology end-user, André Fourie, head of water security and environmental value at SABMiller, stated: “There is only one reason why our European business is ahead of the rest – and that’s because [F-Gas] Regulation has moved faster in Europe.”

3.2 Governments around the world take inspiration from the EU

“The concept of the HFC phase-down has been taken up in other jurisdictions, we’ve certainly had inquiries from a number of countries.” *Philip Owen, European Commission*

Besides the impact that the EU F-Gas Regulation has had on industry outside of Europe, it is worth noting the influence it has had on other national and regional legislative frameworks outside of Europe as well as in international discussions with regard to addressing HFCs globally. Following the adoption of the EU Regulation, several national and regional governments outside of Europe looked at the legislative work that has been done in Europe when designing their own rules regulating the use and emissions of HFCs.

Commenting on the interest that the European Commission has received from other countries, Philip Owen noted: “The concept of the phase-down has been taken up in other jurisdictions, we’ve certainly had inquiries from a number of countries. Canada is legislating a phase-down in a similar structure to what we have in Europe. We’ve had several conversations with the California Air Resources Board over the years and they also have the intention to have a similar sort of structure. Australia had a taxation system first of all, but now quite clearly they are also revising their legislation and probably will legislate next year again with a phase-down, ending in around 2035. We’ve talked to Japan but they have a slightly different system.”

The following pages of this chapter zoom in on how the Regulation has inspired action on fluorinated gases in California

and Japan. In addition, the last part of this section examines the impact of the Regulation on the international discussions that are currently ongoing with regard to limiting the use and emissions of HFCs under the Montreal Protocol.

3.2.1 California aspiring to outstrip the ambition of EU F-Gas Regulation

“The EU F-Gas Regulation is the best existing programme in the world to reduce f-gas emissions. It is the role model for everybody else to follow at this time. While other countries have some strong plans in the works, nobody else has actually been able to pass the legislation needed to significantly reduce f-gases.” *Glenn Gallagher, California Air Resources Board*

The state of California is the leader when it comes to environmental legislation in North America. For the past fifty years the California Air Resources Board (ARB) has helped to put California among the first US states to adopt clean air regulations for so many different polluting sectors, and experience shows that the state’s environmental legislation is eventually adopted nationally for the entire US. For example, ARB’s Refrigerant Management Program, which began in 2011, required best management practices to reduce refrigerant emissions from commercial refrigeration equipment. The US Environmental Protection Agency (US EPA) adopted these best management practices in their 2016 proposed update to existing refrigeration regulations for the nation.

In April 2016, ARB took a step towards curbing emissions of high-GWP HFCs with the publication of its Proposed Strategy to reduce short-lived climate pollutants, which also include methane and black carbon (soot).

While HFCs currently account for 4% of California's GHG emissions, their amount is expected to double in the next few decades if no additional measures are taken. "Fluorinated gases, and in particular HFCs, are the fastest-growing source of GHG emissions in California and globally," reads the proposal. **The Air Resources Board is putting forward actions to cut HFC emissions by 40% by 2030, compared to 2013 levels.** Meeting these targets will help to achieve the Governor's goal to cut all greenhouse gas emissions in California by 40% below 1990 levels by 2030 and help to meet federal air quality standards for 2031 and beyond.

The Proposed Strategy notes that "without early action to reduce unnecessary emissions now and into the future, the State [of California] would need to take additional — likely more costly — steps to meet its 2030 climate targets". The proposal further notes that although low-GWP technologies are assumed to have at least 10% higher initial cost, "in many cases, the added initial cost is offset or reversed through the energy savings of low-GWP refrigeration and air-conditioning. Additionally, low-GWP refrigerants such as carbon dioxide refrigerant, ammonia, and hydrocarbons are less expensive than HFCs".

"It's fair to say that the EU F-Gas Regulation was the primary influence on the development of f-gas reduction measures in California. Although HFC reductions are required by (California Legislative Bill) AB 32, The Global Warming Solutions Act of 2006, the actual mechanisms to reduce HFC emissions were left to the California Air Resources Board (ARB) to determine (in conjunction with a significant amount of stakeholder involvement). The EU F-gas Regulation is the obvious template and example to look to as we develop our own f-gas emissions measures," said Glenn Gallagher, air pollution specialist for the California Air Resources Board (ARB), the key person in charge of developing California's rules to reduce HFC emissions.

Sector-specific HFC bans — a major consideration for California

"The gradual phase-down, while a good idea, could lock in the use of relatively high-GWP equipment for the lifetime of the equipment, with another 10 to 20 years of high-GWP refrigerant emissions...ARB has calculated that sector-specific bans will work to reduce HFC emissions more quickly than a gradual HFC allocation phase-down."

Glenn Gallagher, California Air Resources Board

Similar to the EU F-Gas Regulation, ARB is proposing a combination of measures to reduce HFC emissions, including sector-specific HFC bans in stationary systems, prohibition in the sale of new refrigerants with high GWP (> 2,500) as well as financial incentives.

In the EU and some of the countries that had adopted restrictions on the use of fluorinated refrigerants even before the revised F-Gas Regulation, bans on HFCs in new equipment have proven to be the most effective tool to shift away from fluorinated refrigerants and invest in HFC-free technologies.

The recommended bans for new equipment in ARB's Proposed Strategy would go beyond the EU F-Gas Regulation, potentially making California one of the most advanced regions in terms of HFC legislation. ARB has proposed a ban on HFCs whose GWP is greater than 150 in new commercial and industrial refrigeration, which would start in 2020. Such a ban would be in line with the deadline for phasing out R22, thereby enabling technology end users to go directly to the most climate-friendly solution, avoiding intermediary HFC refrigerants. For residential refrigeration, ARB suggests a ban on HFCs with GWPs above 150 in new equipment, starting in 2021. New stationary air-conditioning equipment (residential, commercial and industrial) is also targeted for prohibition starting in 2021 for HFCs with GWPs greater than 750.

Explaining how the EU Regulation has influenced legislative work in California, Gallagher noted: "The EU F-Gas Regulation sector-specific prohibitions of high-GWP HFCs in new

California foresees a combination of measures to limit the use of HFCs



equipment were an important consideration for us. The prohibition of new single split air-conditioning systems with a GWP of 750 or greater was a good catalyst for us to look into reasonable GWP limits for AC. However, we always felt that the sector-specific prohibitions could have been stronger, and this would have placed less pressure on the HFC phase-down to result in most reductions. Additionally, the phase-down could result in an unfortunate series of transitional equipment changes resulting in lower GWP refrigerants than business as usual, but with GWP values that would still be unacceptably high. This gradual phase-down, while a good idea, could lock in the use of relatively high-GWP equipment for the lifetime of the equipment, with another 10 to 20 years of high-GWP refrigerant emissions."

With California looking at introducing HFC bans across the sector of stationary refrigeration and air-conditioning, they also see areas where the EU legislation could improve. **"ARB has calculated that sector-specific bans will work to reduce HFC emissions more quickly than a gradual HFC allocation phase-down. The existing sector-specific prohibitions in the EU F-Gas Regulation could be amended to include additional types of equipment, not just the very large refrigeration and the small AC equipment as currently covered."**

Another key measure proposed to reduce the use of high-GWP refrigerants is a prohibition on the sale of new refrigerants with GWP values greater than 2,500. Here California intends to go a step further than the EU, by suggesting implementation of such a measure two years earlier, beginning in 2020. Such a ban would facilitate a much faster transition from very high-GWP refrigerants to lower-GWP alternatives in existing equipment (thus avoiding the ongoing high-GWP emissions from equipment that typically lasts for 15 years or longer).

California could align with EU HFC phase-down

"The cost of the transition to low-GWP refrigerants has been less than initially anticipated, the alternatives are technically feasible and appear to work very well, and there have even been demonstrated energy efficiency gains."

Glenn Gallagher, California Air Resources Board

While no concrete plans for an HFC phase-down have been proposed, ARB intends to put forward such a proposal in its final strategy, depending on the progress made this year at the Montreal Protocol meetings. In case a global commitment cannot be reached, California would look to align with the phase-down schedules of the EU, as well as Canada, Australia and Japan. Gallagher believes that the HFC phase-down adopted under the EU F-Gas Regulation has already sent a strong signal to the market that business as usual for the HVAC&R industry will change. "Clearly, having an HFC phase-down already in the Regulation gives market certainty for the EU, and we would expect that a global HFC phase-down will have the same effect on the rest of the world," said Gallagher.

He believes the EU Regulation demonstrates that, "an HFC phase-down can be accomplished economically and without disrupting businesses that rely on refrigeration and air-conditioning. The cost of the transition to low-GWP refrigerants has been less than initially anticipated, the alternatives are technically feasible and appear to work very well, and there have even been demonstrated energy efficiency gains. The bottom line is that low-GWP refrigeration and air-conditioning works and is cost-effective".

3.2.2 Japan's revised F-Gas Law addresses the full lifecycle of HFCs

"Technology using natural refrigerants has been improved in efficiency and safety, but not yet spread widely. To address this situation, the Ministry of Environment financially supports installations of high-efficiency equipment with natural refrigerants," Motoyuki Kumakura – director of the Office of Fluorocarbons Control Policy, Ministry of Environment

Alongside the EU and California, Japan's government has set another example of advancing domestic legislation governing the use of HFCs with its revision of the F-Gas Law, ahead of any international agreement.

Japan's F-Gas Law was revised almost simultaneously alongside the EU F-Gas Regulation. When designing the new rules Japan carefully examined the policies that other countries and regions, including the EU, were adopting or considering adopting in order to limit the use of HFCs. While the original fluorocarbon regulations focused on the recovery and destruction of fluorocarbons from disposed commercial air-conditioning and refrigeration units, the revised Law that entered into force in April 2015 introduced new policy measures that address the full lifecycle of HFCs. With the new legislation, Japan took a similar approach to the EU in that it introduced a combination of measures to address emissions of f-gases.

While the measures adopted have been adapted to the technology status and legislative processes in Japan, many points of the new rules are comparable to the EU's F-Gas Regulation. These include reporting, which is now mandatory for producers and importers of f-gases, as well as leak checking for end users, the phase-down of HFCs, and the promotion of low-GWP / non-fluorocarbon refrigerants in designated products.

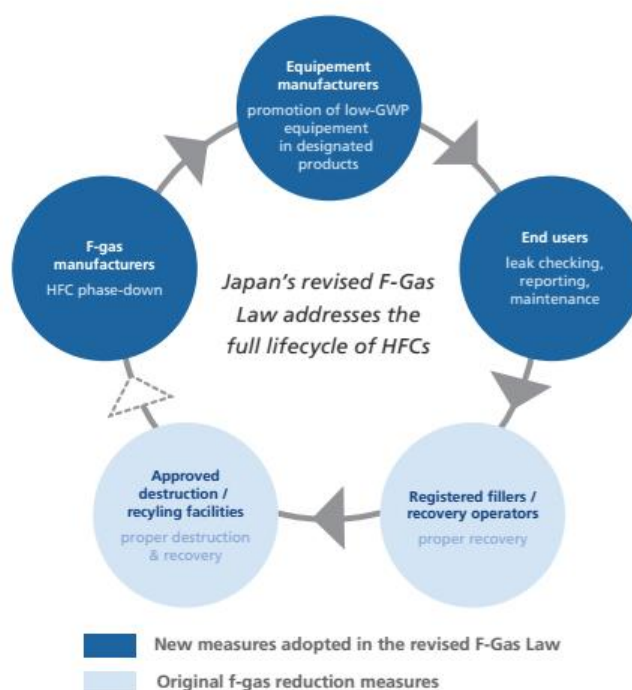
Specifically, the regulatory measures encourage entities involved in each process of the lifecycle to carry out the following:

- 1) Entities that manufacture and import fluorocarbons:** To reduce environmental impact through technology development and manufacturing of fluorocarbons with lower global warming impact, and the recycling of set amounts of used fluorocarbons.
- 2) Entities that manufacture and import products using fluorocarbons:** To change from products using fluorocarbons in certain product categories, such as freezer show-

cases, to either fluorocarbon-free products or products using fluorocarbons with low global warming impact, by certain target years depending on the product category. This measure is comparable to the EU's sector-specific bans, but instead of imposing a strict prohibition, Japan has opted for setting target GWP values that need to be reached by each manufacturer by a certain year.

- 3) Users that manage commercial air-conditioning and refrigeration units:** To properly manage such units in order to prevent the leakage of fluorocarbons through proper installation and inspection, as well as to repair damaged units. Moreover, certain users are required to submit an annual report on the amount of fluorocarbons leaked, and the data is compiled and disclosed by the Government of Japan. If the top-up of refrigerant due to leakages exceeds certain quantities, it will be prohibited.
- 4) Proper filling of air-conditioning and refrigeration units with fluorocarbons and proper recycling of used fluorocarbons:** The revised Law introduced a registration system for entities that fill commercial air-conditioning and refrigeration units with fluorocarbons, as well as a permission system for entities that recycle fluorocarbons.

Preliminary calculation of the effects of HFC emission reduction measures made by the Ministry of Environment (MOE) and the Ministry of Industry (METI) indicate that the promotion of f-gas alternatives can help achieve substantial emissions reductions – 10 times more than containment measures in commercial refrigeration equipment by 2030.



GWP targets for 'designated products'

Instead of imposing restrictions on the use of high-GWP refrigerants in certain applications, as is the case in the EU F-Gas Regulation, the Japanese law sets GWP targets per product group, which each manufacturer needs to reach by a certain target year.

The GWP targets are set for the sectors with the highest environmental impact where it has been proven that non-fluorinated refrigerants or other low-GWP substances are commercially available and energy-efficient. Weighted average GWP values of entire production and imports are taken into account to measure compliance by manufacturers.

GWP targets for designated products

Designated products	Present refrigerant (GWP)	Target value (GWP)	Target year
 Room air-conditioning	R410A (2,088), R32 (675)	750	2018
 Commercial air-conditioning (offices & stores)	R410A (2,088)	750	2020
 Condensing units and refrigeration units (> 1.5kW)	R404A (3,922), R410A (2,088), R407c (1,774), CO ₂ (1)	1,500	2025
 Cold storage warehouse (> 50,000m ³)	R404A (3,922), NH ₃ (0)	100	2019
 Mobile air-conditioning	R134a (1,430)	150	2023

Financial support for end users drives market for natural refrigerants

The support of end users in adopting HFC-free technology is a very effective tool that helps achieve the objectives of the F-Gas Law.

Besides the regulatory requirements concerning the production, use and end of life of f-gases, the Japanese Ministry of Environment (MOE) initiated a subsidy scheme, which has provided significant benefits for companies and organisations opting for and working with natural refrigerants. The scheme, designed to accelerate the introduction of natural refrigerants, was first put in place in 2005, and has been in full gear since 2014.

“Technology using natural refrigerants has been improved in efficiency and safety, but not yet spread widely. To address this situation, the Ministry of Environment financially supports installations of high-efficiency equipment with natural refrigerants,” said Motoyuki Kumakura, director of the Office of Fluorocarbons Control Policy, Ministry of Environment.

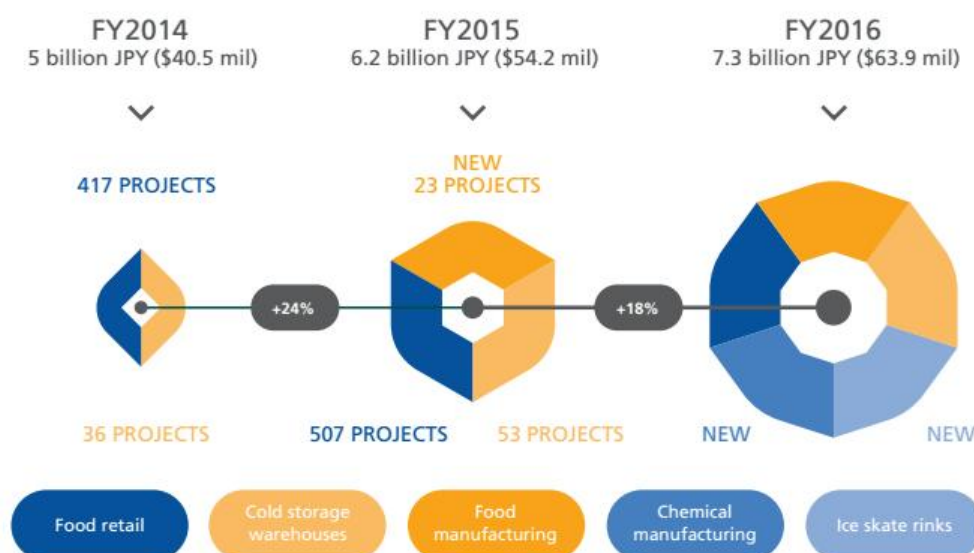
The support of end users in adopting HFC-free technology is a very effective tool that helps achieve the objectives of the F-Gas Law. While such an approach would not be possible at the EU level, individual Member States can take inspiration from the experience of Japan in supporting their businesses nationally.

Since 2014, Japan’s subsidy scheme has not only seen its budget and thereby the number of projects supported increase, but its scope has also been extended to cover additional applications, creating opportunities for innovative companies in Japan that have invested in the development of natural refrigerant-based technologies.

The budget of five billion JPY in FY2014 was increased by 24% for FY2015 (6.2 billion JPY) and again by 18% for FY2016 (7.3 billion).

Initially (in 2014), the subsidy scheme covered support of display refrigerators in food retail and refrigeration technology for cold storage warehouses. In 2015, the food manufacturing sector was added. Most recently, the scheme will also cover chemical manufacturing processes and ice skate rinks in FY2016.

Japan’s subsidy growing in scope and budget



3.2.3 EU working to promote an ambitious global HFC phase-down under Montreal Protocol

"A global reduction in the use of HFCs will constitute a clear step forward in the fight against climate change. It is a quick and cost effective way of getting on track with the ambitious goals we set ourselves in Paris. This is why the EU is committed to working towards the adoption of an amendment to the Montreal Protocol this year."

EU Commissioner for Climate Action and Energy, Miguel Arias Cañete

The EU is an important and influential actor in international environmental negotiations. As a party to the Montreal Protocol, which currently mandates the use of ozone-depleting substances (ODS), the EU and its Member States have always led by example in going beyond international requirements, for example by phasing out HCFCs early.

Amid growing concern regarding the increase in emissions of HFCs, which have essentially replaced the ozone-depleting substances, efforts have been intensifying to include the phase-down of HFCs under the Montreal Protocol. Achieving a global solution to curb HFC emissions could save around 80 Gigatonnes of CO₂ equivalent emissions (GtCO₂e) by 2050. A global HFC phase-down would deliver a significant contribution to the fight against climate change.

EU's HFC phase-down – blueprint for global action

"We were inspired because we had leadership; we had a lot of credibility following the F-Gas Regulation. We proved that the phase-down could be legislated for and we had the data to show that there were alternative substances for many applications."

Philip Owen, European Commission

The EU F-Gas Regulation's HFC phase-down has set a precedent for advancing reductions of high global warming gases and replacing them with readily available climate-friendly alternatives, such as natural refrigerants. It shows that cost-effective reductions of HFCs are possible without unnecessary delays. The introduction of the EU's phase-down, in combination with other measures, has indeed demonstrated that the industry is able to switch to energy-efficient, safe and cost-effective alternatives once there is a clear legislative signal.

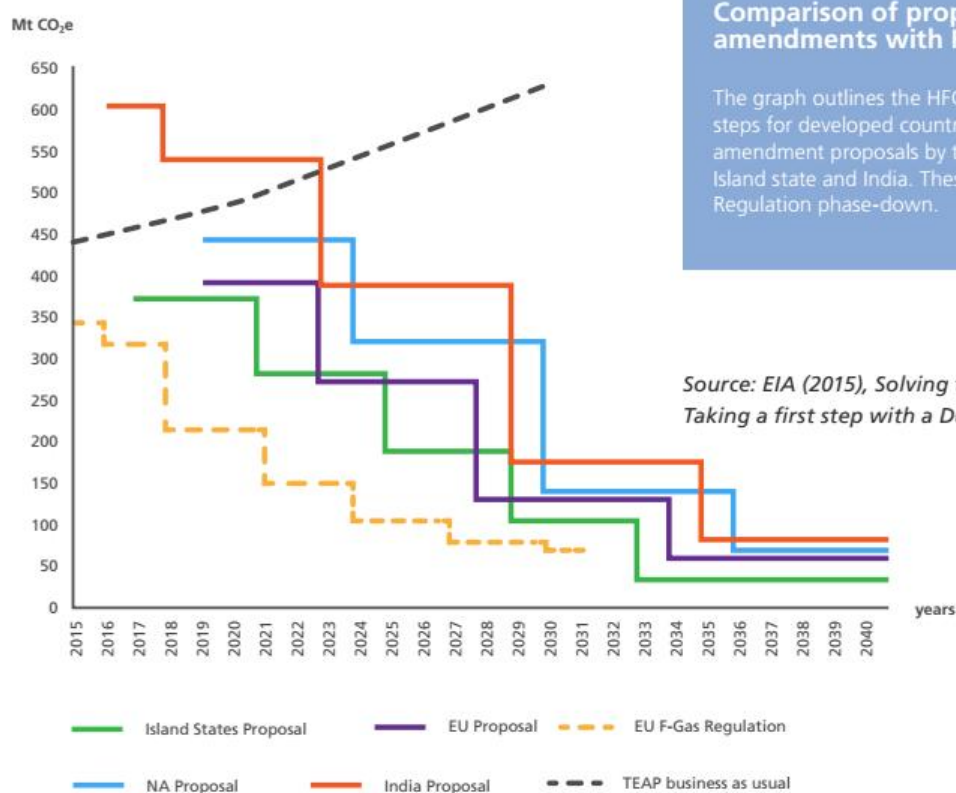
To facilitate reaching a global consensus, in April 2015 the EU submitted an amendment proposal to phase down the use of HFCs under the Montreal Protocol. The EU's move follows similar proposals submitted since 2009 by the USA, Canada, Mexico and Micronesia (together with other Island States), and would significantly reduce HFCs in developed countries

by following a phase-down structure that has been inspired by the F-Gas Regulation.

“The EU always likes to be an environmental leader, but quite clearly we were not the first to come forward with a proposal for the Montreal Protocol. We were inspired because we had leadership; we had a lot of credibility following the F-Gas Regulation. We proved that the phase-down could be legislated for and we had the data to show that there were alternative substances for many applications, so we’ve done that basic work to show what was possible,” said the European Commission’s Philip Owen, explaining the motivation behind the EU’s proposal to amend the Montreal Protocol.

“There is a European industry angle as well because European companies have to find alternatives. If we are creating a worldwide phase-down to the Montreal Protocol, that will also create business opportunities for them to actually market their alternatives. So there is an industrial policy aspect to this as well as purely environmental policy,” Owen added.

For the European Commission, an early action without further delays is important. “What was very clear from our proposal is that we wanted early action – as we have the F-Gas Regulation starting in 2015 we proposed an early start for work under the Montreal Protocol. We know that as the volume of f-gases will grow an early action to freeze, to phase down will reduce the actual compliance costs, which the donor countries have to pay,” he underlined.



EU taking different approach

Under the EU's proposed amendment, industrialised economies are called on to take the lead by committing to a phase-down schedule beginning in 2019 using the combined 100% HFC / 45% HCFC baseline for the period 2009-2012 (expressed in CO₂ equivalent). The production and consumption of HFCs would gradually be reduced by 15% in 2019, 40% by 2023, 70% by 2028, and 85% by 2034.

Developing countries (operating under Article 5 of the Montreal Protocol) would use baselines calculated from their average 100% HFC / 70% HCFC production in 2009-2012 (in CO₂e) and their average HFC/HCFC consumption in 2015-2016 (in CO₂e) and freeze those levels by 2019. The EU amendment suggests that a reduction schedule and steps should be agreed by 2020.

The approach of distinguishing the baselines, freezing emissions, and taking steps for emission reductions in developing and developed countries has been taken up in all other amendment proposals that are currently on the table (North American, Island States and Indian proposals). This follows the principle of 'common but differentiated responsibilities'. What differentiates the EU proposal from the others, besides differences in the timelines and reduction steps, is the measurement of the HFC baselines and reduction steps in CO₂ equivalent rather than metric tonnes, which has been inspired by the EU F-Gas Regulation. "When the North American countries came up with the first proposal to amend the Montreal Protocol they came up with a metric tonne approach. After we've done our F-Gas Regulation and we were discussing our proposal for the Montreal Protocol they also changed to a CO₂-based approach. This makes a huge amount of sense because we recognise that today there are not alternatives for all applications, but we will certainly always try and push the use of the lowest-GWP gases wherever possible," explained Owen.

Compared to the F-Gas Regulation, the phase-down proposed under the amendment proposal is less ambitious. This is due to the fact that the EU had to take into account that other countries or regions might not be as advanced in addressing HFCs at national level. "It is important to know that the EU had been an early mover and we had phased out HCFCs effectively in 2010. So when you are actually establishing the baseline, how you take HCFCs into account – which is necessary in other jurisdictions where the HCFC phase-out has not happened so quickly – is important."

Towards a legally-binding deal

"The reality is that if we do this deal we will save up to 0.5°C of global warming, which could be the difference between 2°C or 1.5 °C that we talked about in the Paris Agreement – it's a broader political debate than simply Montreal, it is also very much a climate debate and that is why there will be a lot of effort to make it actually work. We have to do it!" Philip Owen, European Commission

The EU is flexible on the details of the amendment, provided the outcome is ambitious in reducing emissions in both developed and developing countries. EU Member States remain committed to providing additional financial and technical support to developing countries to help them comply with any HFC obligations agreed under the Montreal Protocol.

Reflecting on this year's international negotiations to phase down HFCs, Owen was hopeful that a deal would be made at the 28th Meeting of the Parties in Kigali, Rwanda. "The reality is that if we do this deal we will save up to 0.5°C of global warming, which could be the difference between 2°C or 1.5°C that we talked about in the Paris Agreement – it's a broader political debate than simply Montreal. It is also very much a climate debate and that is why there will be a lot of effort to make it actually work. We have to do it!"

The amendment – which would be legally binding on the 197 Parties to the Montreal Protocol – could potentially make a greater contribution to reducing greenhouse gas emissions than the Paris Agreement struck during UNFCCC talks at the end of 2015, in which the pledges made by countries to reduce their emissions are voluntary.

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Get in touch with shecco team to learn more about the market for natural refrigerants or find out how we can help you in gathering market intelligence and proactively building your business with our tailored market development services, to get your technology faster to market.

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