ATMO Report

2022 Edition

Natural Refrigerants: State of the Industry

Commercial and Industrial Refrigeration in Europe, North America and Japan

Panasonic

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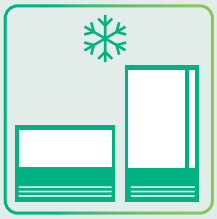

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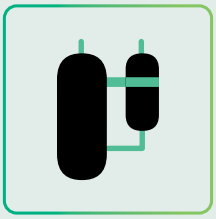

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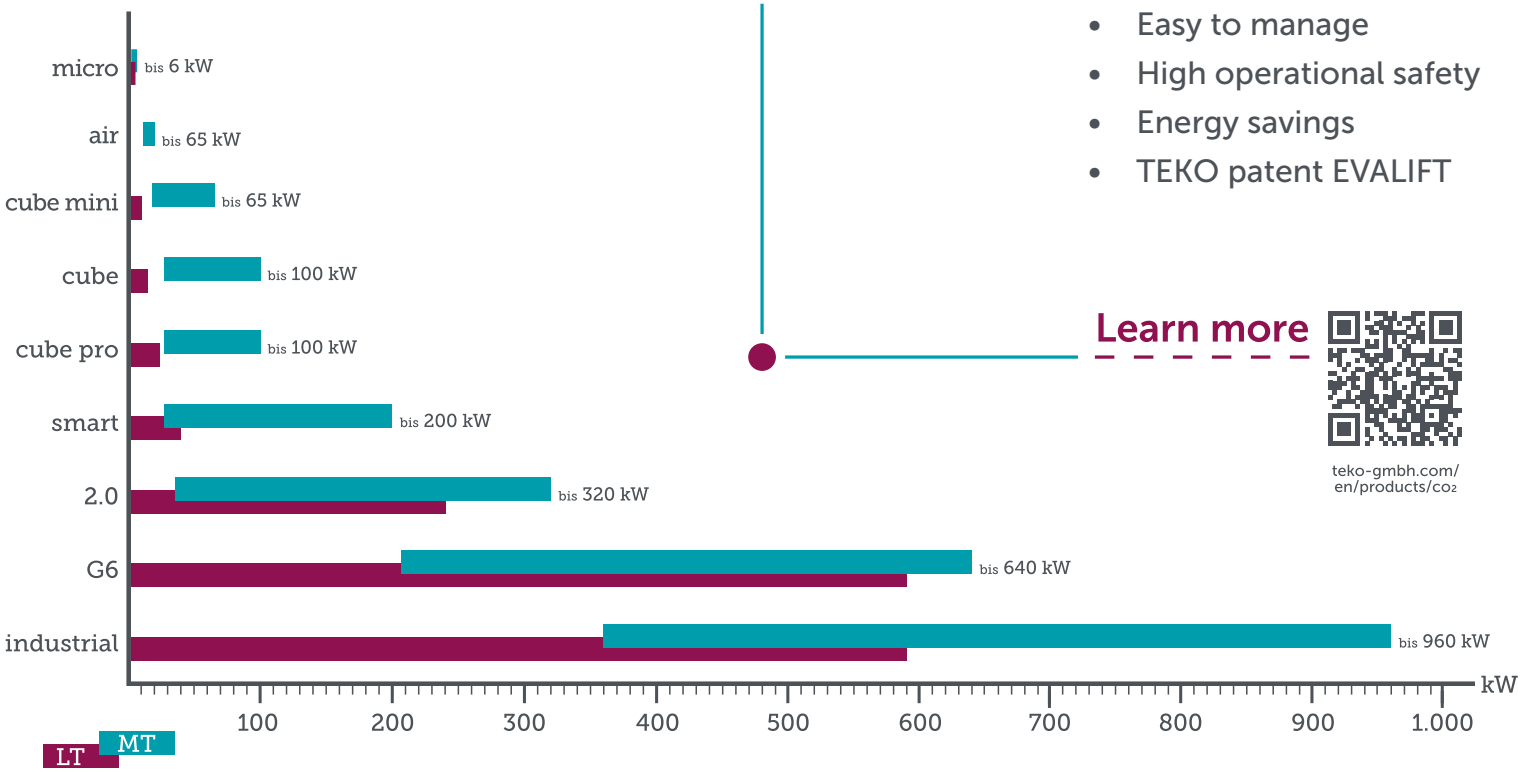

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2022 EDITION

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Originally published in February 2023.

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ATMO Report

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About Us

Founded in 2007 as shecco, ATMOsphere is a global, independent market accelerator for clean cooling and heating and natural refrigerant solutions. The company boasts more than 50 years of industry experience throughout its global team located in Europe, Japan and the U.S.

ATMOsphere combines the company's extensive natural refrigerant expertise with the power of its wider network of like-minded experts who share an ambition for scaling up the global clean-cooling economy.

ATMOsphere's business includes product and news marketplaces, events and market research. In addition, in June 2022, ATMOsphere launched its natural refrigerants label as a global gold standard highlighting best-in-class manufacturers of natural refrigerant systems and components around the world.

Overall, the ATMOsphere platform offers a one-stop solution for – among others – investors, end users, original equipment manufacturers (OEMs), component manufacturers, contractors and others who want to scale up clean cooling.

The ATMOsphere core team includes journalists, analysts, engineers, event organizers, designers and other highly skilled individuals with a diverse background – all working together to gather information and analyze this niche market. As industry experts in this field, the team offers unique insights into trends and market size that cannot be replicated by organizations without the same history and network.

However, the real power of the ATMOsphere brand lies in its network. It spans the whole globe and includes more than 50,000 industry stakeholders – from policymakers and end users to academia, manufacturers and everyone in between.

ATMOsphere is not just a company, but a network, a community of people who believe that the future of cooling is clean and natural.

For more information, visit atmosphere.cool

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ATMOsphere Natural Refrigerants Label

ATMOsphere has launched a global industry label to meet growing market demand for a quality label that qualifies and celebrates the best natural refrigerant companies and products.

Aimed at natural refrigerant manufacturers (both system and component), our custom process considers company vision, customer satisfaction, and measurable impact.

atmosphere.cool/natural-refrigerants-label/

The State of Our Market is Strong

It took four long years, but the HVAC&R industry finally reconvened at Chillventa in Germany last October. It was a rewarding week reconnecting with friends, partners and colleagues across the many halls and stands at the Nuremberg Exhibition Centre.

We met at a disconcerting time, as Russia continued to inflict misery upon Ukraine. Gas and food prices remained high across Europe, supply chains were sluggish, and lingering uncertainty persisted about the course of COVID-19.

And yet, with regard to the natural refrigerants marketplace in Europe, there was much to applaud. We have just completed a very strong year for adoption of natural refrigerant-based systems and equipment in the commercial and industrial sector, not only in Europe, but in North America and Japan as well, as we describe in this State of the Industry report.

Over the past 18 months, transcritical CO_2 has grown at an amazing rate as stores continue to install racks and (in Europe and Japan) condensing units, as well as hydrocarbon-based cabinets. And we are seeing progress for CO_2 and low-charge ammonia systems in the industrial sector as well.

We hope that this annual State of the Industry report, based on considerable research by the ATMOsphere team, will provide evidence of the strength of the natural refrigerants market in Europe, North America and Japan, the leading global markets for this technology. It is meant to provide a review of systems, market trends and policy changes, elevating the discourse around natural refrigerants and enabling our readers to plan for the year ahead.

In the years ahead, we will add new regions and applications to the report.

It's true that business could have been better over the past year were it not for the external shocks brought about by Russia and the after-effects of COVID. Yet, today, in commercial refrigeration, CO_2 is seen as a standard refrigerant, business as usual, across large and small formats and in every part of the European continent, and is picking up steam in North America and Japan. It's no longer just for Northern countries, but for all, regardless of geography or climate.

There are now thousands of companies around the world that are part of a massive natural refrigerants eco-system, including end users, contractors, installers, and manufacturers of integrated systems and components. This robust and knowledgeable eco-system, years in the making, has literally transformed the commercial and industrial refrigeration marketplace in Europe into one that embraces natural and clean cooling solutions.

And this will only grow in the years ahead, so that by the end of the decade, natural refrigerants will represent the vast majority of commercial and industrial installations in many parts of the industrialized world. It's only a matter of time before this wave overtakes other applications such as heat pumps and AC, and transport refrigeration, among other residential, commercial and industrial applications.

The fundamental appeal of natural refrigerants remains undeniable, even in the face of the societal headwinds we are now facing.

Marc Chasserot
Founder & Publisher
ATMOsphere

Introduction

In this 2022 State of the Industry ATMOsphere report, we assess the state of the natural refrigerants marketplace for commercial and industrial refrigeration in Europe, North America and Japan.

As an American, I have always marveled at the progress European countries and Japan have made in moving from f-gases to natural refrigerants, far surpassing what has been accomplished to date in the U.S.

In 2021 we estimated there were 900 sites (mostly supermarkets and some industrial facilities) where transcritical CO_2 systems were installed in the U.S. That number grew to 1,150 in 2022, with an additional 745 CO_2 sites in Canada for a total of 1,895 in North America.

In Europe, we determined there were 40,000 CO_2 sites in 2021. In 2020, we saw an even more robust European market, comprising 50,000 stores with transcritical CO_2 racks, 5,000 with CO_2 condensing units and 2,000 industrial facilities with CO_2 systems, for a total of 57,000 CO_2 sites. Meanwhile the number of CO_2 sites in Japan grew from 6,060 in 2021 to 6,960 in 2022.

Europe has also been a leader in the installation of hydrocarbon-based self-contained cabinets in stores, both on a spot basis in combination with centralized systems and throughout the store. This year, we are seeing a total of 2.9 million such cases in the European marketplace, up from 2.7 million last year. In the U.S., the number of installed hydrocarbon commercial cases increased from 875,000 in 2021 to 919,000 in 2022.

We also saw an uptick in the number of industrial sites in Europe using low-charge ammonia systems, to 2,850 in 2022, while in the U.S. it was 650 and in Canada, 300.

Of course, Europe's embrace of natural refrigerants is based on its rejection of f-gases through its F-gas Regulation, first enacted in 2006, and soon to be updated again. The U.S. is making progress with its rollout of the AIM Act, while Japan continues to offer subsidies for the installation of natural refrigerant-based systems.

And now the EU is poised to become the first world governmental body to evaluate another threat posed by the latest generation of f-gases, HFOs. Next year, the European Chemicals Agency (ECHA) will consider a proposal to restrict some HFC and HFO refrigerants – as well as an atmospheric byproduct of some f-gases, trifluoroacetic acid (TFA) – as per- and polyfluoroalkyl substances (PFAS). PFAS are known as "forever chemicals" for their persistence in the environment, which makes them a threat to human health.

The report also looks at global trends affecting the growth of natural refrigerant systems. These include such key developments as the rapid advances in digitalization, online grocery shopping and cooling-as-a-service. We also provide an update on the latest technologies supporting the efficient use of transcritical CO_2 systems, hydrocarbon cases and low-charge ammonia systems.

Michael Garry
Head of Content
ATMOsphere

Methodology

In this 2022 State of the Industry report on natural refrigerants, ATMOsphere investigates the state of the market for key natural refrigeration technologies in commercial and industrial applications in Europe, North America and Japan, the leading and fastest-growing markets for natural refrigerant systems in the world.

To fully understand and analyze these markets, the ATMOsphere team used a combination of qualitative and quantitative research methods, leveraging our expansive knowledge and experience with the subject matter, as well as ATMOsphere's global network of natural refrigerant experts.

The following methods were used:

Desk Research

Desk research was conducted regarding the current state of the commercial and industrial refrigeration markets, policy trends and the available natural refrigerant-based options.

ATMOsphere leveraged a combination of external reports, academic publications, together with its own articles and reports, to build an understanding of the market.

As the leading market accelerator for natural refrigerants, ATMOsphere is powered by a database of natural refrigerant and clean cooling information, diligently collected over the years by its analysts and journalists

Data Collection

The primary source of market data for the European market was via an industry survey designed by the ATMOsphere team and sent to key European OEMs of natural refrigerant-based CO_2 systems (racks and/or condensing units), low-charge (below 1.3kg/kw or 10.1/bs/TR) ammonia systems, and hydrocarbon-based self-contained retail cabinets.

The European market is defined as encompassing the European Union as well as the U.K., Norway, Switzerland, Iceland, non-EU Balkan states, Ukraine, Belarus, Moldova and the European part of Russia.

For the North American and Japanese markets, in lieu of a survey, in-depth interviews were held with the key suppliers of natural refrigerant-based systems.

In all regions, manufacturers of CO_2 racks and condensing units were asked to provide the approximate number of stores (new and existing) and/or industrial facilities (new or existing) in Europe that have installed their equipment.

Manufacturers of low-charge ammonia systems (packaged or centralized, including NH_3/CO_2 systems) were asked to provide the approximate number of industrial facilities (such as cold storage or food processing, new or existing) that have installed their equipment.

Manufacturers of hydrocarbon-based self-contained refrigerated- and/or frozen-food retail cabinets were asked to provide the approximate number of units (air- and water-cooled) they have sold.

All companies were asked to provide an approximation of their market share of stores and/or industrial facilities using their equipment, or their market share for hydrocarbon cabinets.

All companies were guaranteed that their data would be kept in confidence and only used anonymously in combination with data received from other companies to create an aggregate picture at the marketplace.

The survey and interviews received responses from OEMs of transcritical CO_2 equipment, low-charge ammonia equipment and hydrocarbon cabinets that together represent a substantial share of the market for natural refrigerant equipment in Europe, North America and Japan.

We also leveraged public data on natural refrigerant system installations from other OEMs available on their websites, provided at conferences, in interviews with ATMOsphere journalists, or other sources. Additional data was gathered with the help of industry associations.

Note that our data indicates the number of sites (locations, whether stores or industrial facilities) using CO_2 or ammonia equipment. An individual site could use more than one system (rack) or condensing unit. However, the number of cabinets (units) is indicated for hydrocarbon-based equipment.

Interviews with Key Industry Stakeholders

ATMOsphere also contacted a number of end users, academics and other experts to improve its understanding of current trends and the state of the market for natural refrigerant installations.

Abbreviations

AIM Act – American Innovation and Manufacturing Act
BASE – Basel Agency for Sustainable Energy
CaaS – Cooling as a Service
CARB – California Air Resources Board
CDA – Copper Development Association
CO_2e – CO_2 equivalent
COP – Coefficient of Performance
CSA – Canadian Standards Association
DOE (U.S.) – Department of Energy
EC – European Commission
ECOS – Environmental Coalition on Standards
ECHA – European Chemical Agency
EIA – Environmental Investigation Agency
EPA (U.S.) – Environmental Protection Agency
EPBR – European Productivity and Benchmarking Research
EPREL – European Product Register for Energy Labelling
ETE – Extreme Temperature Efficiency
EU – European Union
F-Gas – Fluorinated Gas
FMI – The Food Industry Association
FTE – Full Transcritical Efficiency
GCCA – Global Cold Chain Alliance
GHG – Greenhouse Gas
GWP – Global Warming Potential
HCFC – Hydrochlorofluorocarbon
HFC – Hydrofluorocarbon
HFO – Hydrofluoroolefin
HVAC&R – Heating, Ventilation, Air-Conditioning & Refrigeration
ICC – International Code Council
IEA – International Energy Agency
IEC – International Electrotechnical Commission
IIAR – International Institute of Ammonia Refrigeration
IPCC – Intergovernmental Panel on Climate Change
IRA – Inflation Reduction Act
JARW – Japan Association of Refrigerated Warehouses
JIS – Japanese Industrial Standard
JRAIA – Japan Refrigeration and Air Conditioning Industry Association
KHK (Japan) – High Pressure Safety Institute
LFL – Lower Flammability Limit
MAC – Mobile Air-Conditioning
MFC – Microfulfillment Center

MOE (Japan) Ministry of the Environment
OECD – Organisation for Economic Co-operation and Development
OEM – Original Equipment Manufacturer
OCU – Outdoor Condensing Unit
PEER (U.S.) – Public Employees for Environmental Responsibility
PFAS – Per- and Polyfluoroalkyl Substances
REACH (EU) – Registration, Evaluation, Authorisation and Restriction of Chemicals
RMP (U.S. EPA) – Risk Management Program
SNAP (U.S. EPA) – Significant New Alternatives Policy
TFA – Trifluoroacetic Acid or Trifluoroacetate
UBA – German Environmental Agency
UL – Underwriters Laboratories

Natural Refrigerants

R744 – Carbon Dioxide (CO_2)
R717 – Ammonia (NH_3)
R290 – Propane
R600a – Isobutane
R1270 – Propylene/Propene
R718 – Water
R729 – Air

Executive Summary

KEY TRENDS

Europe

The European grocery retail market in 2021 was shaped by the ongoing effects of the COVID-19 pandemic, the gradual reopening of the hospitality sector, the emergence of instant delivery (quick commerce) players and price inflation.

COVID-19's impact on the supply chain has generally caused delays, but not cancellations, of new refrigeration equipment and store construction. In 2022, the Russian invasion of Ukraine has had a pronounced impact on the food and refrigeration sectors, exacerbating supply chain issues and inflation.

At the same time, due to increased lead times and the challenge in maintaining the quality of perishable products, companies are relying more on cold storage warehousing to improve a product's life cycle.

The EU F-gas Regulation continues to have the biggest influence on natural refrigeration adoption. As of January 1, 2022, the F-gas Regulation banned use of new commercial systems with a capacity above 40kW (larger systems) that employ a refrigerant whose GWP exceeds 150. This supports natural refrigerant adoption in larger commercial systems. Adoption of plug-in cases using hermetically sealed compressors is also supported as the regulation banned refrigerants with a GWP higher than 150 for that equipment starting in 2022.

The European Commission (EC) on April 5, 2022, released its long-awaited proposal updating the EU F-gas Regulation with measures to further clamp down on HFC use in the EU, opening up more opportunities for natural refrigerants.

Key parts of the proposal include accelerating the HFC phase down from 2024 onward – which would reduce HFC use to 2.4% of 2015 levels by 2048 – and improving enforcement and implementation.

On the standards front, CENELEC, which is responsible for publishing European (EN) standards, published the 500g charge limit for hydrocarbons in commercial cabinets under EN 600335-2-89 in August 2022, raising it from 150g. But the standard must still be included in the list of harmonized standards with the EU Machine Directive (MD) before it can be used as a reference by industry.

In a move with major implications for the European HVAC&R industry, five European countries – Germany, the Netherlands, Norway, Sweden and Denmark – announced in July 2021 their intention to submit a joint proposal to restrict per- and polyfluoroalkyl substances (PFAS), including some HFC and HFO refrigerants, to the European Chemicals Agency (ECHA) under the REACH regulation. ECHA will consider the proposal in 2023. Meanwhile, the uncertainty will hurt HFOs and help natural refrigerants.

North America

Over the past few years North American grocers have been able to increase their capital expenditures, which includes refrigeration, at an amount 1.3 times their historical levels, thanks in part to an influx of funding. The growth of investment in cold storage construction was also robust in 2022, which brought increased investment in natural refrigerant-based refrigeration systems.

Inflation sharply elevated food prices in North America in 2022. However, helped by diminishing gasoline prices, overall inflation rates have eased, dropping in December to 6.5%, the sixth consecutive month of decline. Moreover, the yearly inflation rate is expected to drop to 3.2% by the end of 2023. Other challenges remain, such as the improved but still-fragile supply chain.

On the policy side, the rollout of the American Innovation and Manufacturing (AIM) Act is having a major impact on the refrigeration industry, boosting uptake of natural refrigerants in the U.S. It consists of three parts: phasing down the production and consumption (imports) of listed HFCs, managing these HFCs and their substitutes (including reclamation and leak management), and facilitating the transition to next-generation technologies. The AIM Act aligns the U.S. with the HFC phase-down goals of the Kigali Amendment to the Montreal Protocol, which the U.S. joined last October.

In the U.S., UL (Underwriters Laboratories) approved a second edition of the UL 60335-2-89 standard, including higher charge limits for hydrocarbon and A2L (less flammable) refrigerants. But the U.S. Environmental Protection Agency still needs to follow suit by incorporating the updated UL standard in its SNAP (Significant New Alternatives Program).

The definition of PFAS used by the U.S. Environmental Protection Agency (EPA) should be broadened to include chemicals such as certain HFC and HFO refrigerants, as well as refrigerant byproduct trifluoroacetic acid (TFA), according to a scientist from the Green Science Policy Institute (GSPI).

The California Air Resources Board (CARB) In December 2020 voted unanimously to approve a sweeping regulatory proposal putting in place stronger restrictions on the use of refrigerants in HVAC&R applications than current rules. Last October, California built on its 2020 regulation by enacting SB 1206, aimed at the sale or distribution of bulk HFCs or HFC blends, and designed to increase the adoption of natural refrigerants.

New York has also initiated a new rulemaking under NYCRR Part 49490 that proposes new GWP thresholds for new and existing facilities. Notably, New York, unlike the EPA or other states, uses a 20-year GWP value rather than the traditional 100-year GWP value. Washington has also launched new rulemaking update that will establish GWP thresholds for HFCs used in new equipment and create a refrigerant management program.

In Canada, the Kigali Amendment was ratified in November 2017, and was followed by a phase down of HFC production and consumption that went into force on April 18, 2018. This phase down began in 2019 with a 10% reduction of the baseline, leading up to an 85% reduction in 2036, in alignment with the Kigali Amendment.

Canadian government incentives have supported the uptake of natural refrigerants. In 2023, the federal government is expected to start offering carbon offset credits for projects that cut refrigerant emissions.

Japan

Most transcritical CO_2 systems in Japan are installed at convenience stores such as Lawson.

Japan's revised f-gas laws, which came into effect in April 2015, have created a greater impetus for the uptake of CO_2 systems within the commercial refrigeration sector. But on the while, progress toward natural refrigerants is slow. This is because Japan's f-gas laws focus on the life cycle of refrigerants and introduce target years and target weighted average GWPs that are in some cases very unambitious in comparison to the EU F-gas Regulation.

For example, condensing units in the commercial refrigeration sector have a target weighted average GWP of 1500 by 2025. Such a high GWP target doesn't incentivize the majority of local manufacturers to invest in natural refrigerants, they instead gradually shifted to HFO blends like R448A to comply.

On the other hand, the industrial refrigeration sector has a target weighted average GWP of 15, so here the move to natural refrigerants (especially NH_3/CO_2 and CO_2) is clear, along with some limited competition from HFOs.

Also, since 2014 government subsidies have been a major driver of growth for natural refrigerant systems and have led to an increase in the number of CO_2 transcritical installations in Japan.

Japan's High Pressure Gas Safety Act restricts the use of CO_2 in large refrigeration systems, subjecting manufacturers to heavy administrative burdens. However, in July 2017, the High Pressure Safety Institute of Japan (KHK) announced that CO_2 would be reclassified under the Act, moving from the strictest level of Group 3 to the least restricted level of Group 1. What this means is that several administrative restrictions such as government notification or permission are no longer required for any manufacturer of CO_2 equipment with a daily refrigeration capacity under 20TR/70.3kW (previously under 3TR/10.6kW).

Japan published Japanese Industrial Standard (JIS) C 9335-2-89:2021 in March 2021. The standard, which was developed based on the IEC 60335 -2-89:2019 standard, specifies the increase in the maximum refrigerant charge for commercial refrigeration equipment as 13 times the Lower Flammability Limit (LFL). For R290, this amounts to 494g (17.4oz).

General Trends

Other trends helping the adoption of natural refrigerants include the rise of online shopping and the growth of the frozen and fresh foods market. Additional positive trends include advancements in digitalized monitoring, greater technician training options, the advent of cooling-as-a-service and Clean Cooling.

Each of the three main natural refrigerants is experiencing trends of their own. CO_2 is benefitting from aggressive adoption by market leaders in food retail, the implementation of technologies that improve the efficiency of transcritical systems in warm climates, the rise of integrated systems, the use of CO_2 in small stores and the adoption of CO_2 in industrial refrigeration. Meanwhile hydrocarbons are finding a myriad of uses in stores, some of which are implementing them throughout the sales floor, and ammonia is being reinvented in low-charge systems.

MARKET SIZE

Europe

ATMOsphere found that the number of stores employing transcritical CO_2 refrigeration has grown significantly. We now estimate that, as of December 2022, there were 55,000 stores with transcritical CO_2 systems in Europe, including 50,000 using a centralized system (racks) and 5,000 using condensing units.

This represents a food retail market penetration of 18.4% – the percentage of food retail stores in Europe estimated to feature transcritical CO_2 – out of an estimated market of 299,025 stores.

There were an estimated 2.9 million hydrocarbon self-contained display cases installed at European stores by the end of 2022, a net increase of about 200,000 cases from June 2021.

The number of industrial sites with transcritical CO_2 in Europe, as of December 2022, was estimated to be 2,000 (3.5% of the 57,000 transcritical CO_2 sites). The number of industrial facilities with low-charge ammonia systems as of December 2022 was estimated to be 2,850.

North America

As of December 2022, there were 1,895 sites (stores and industrial locations) with transcritical CO_2 refrigeration systems in North America (U.S. and Canada), including 1,150 sites in the U.S. and 745 sites in Canada.

In the U.S., there were 1,030 stores and 120 industrial sites using transcritical CO_2 systems while in Canada there were 575 stores and 170 industrial sites equipped with this refrigeration technology.

In North America, commercial installations of transcritical CO_2 systems are almost exclusively at supermarkets and grocery stores. Of the 71,348 supermarkets and grocery stores in North America, the market penetration for transcritical CO_2 refrigeration is 2.2%. If convenience stores, a potential market for transcritical CO_2, are added, then the market penetration of the 229,452 total outlets in North America is 0.7%.

Since 2020, transcritical CO_2 installations in North American stores have grown from 945 to 1,605. In the U.S. CO_2 store installations have increased from 605 to 1,030 while in Canada they have jumped from 340 to 575.

As of December 2022, the number of self-contained hydrocarbon cabinets in U.S. stores was estimated to be 919,000. That's up from 875,000 units, including 500,000 beverage cases, in 2021.

In North America, as of December 2022, there were an estimated 290 industrial sites using transcritical CO_2 refrigeration (15.3% of the total), including 120 (10.4%) in the U.S. (up from 70 in 2021) and 170 (23%) in Canada.

In North America, as of December 2022, there were an estimated 950 industrial sites with installations of low-charge ammonia systems, including 100 with packaged units and 850 with central (engine room) systems. There were 650 industrial sites (570 with central and 80 with packaged systems) in the U.S. and 300 (280 central and 20 packaged) in Canada.

In the U.S., there were 600 industrial sites with low-charge ammonia systems in 2021 and 525 in 2019.

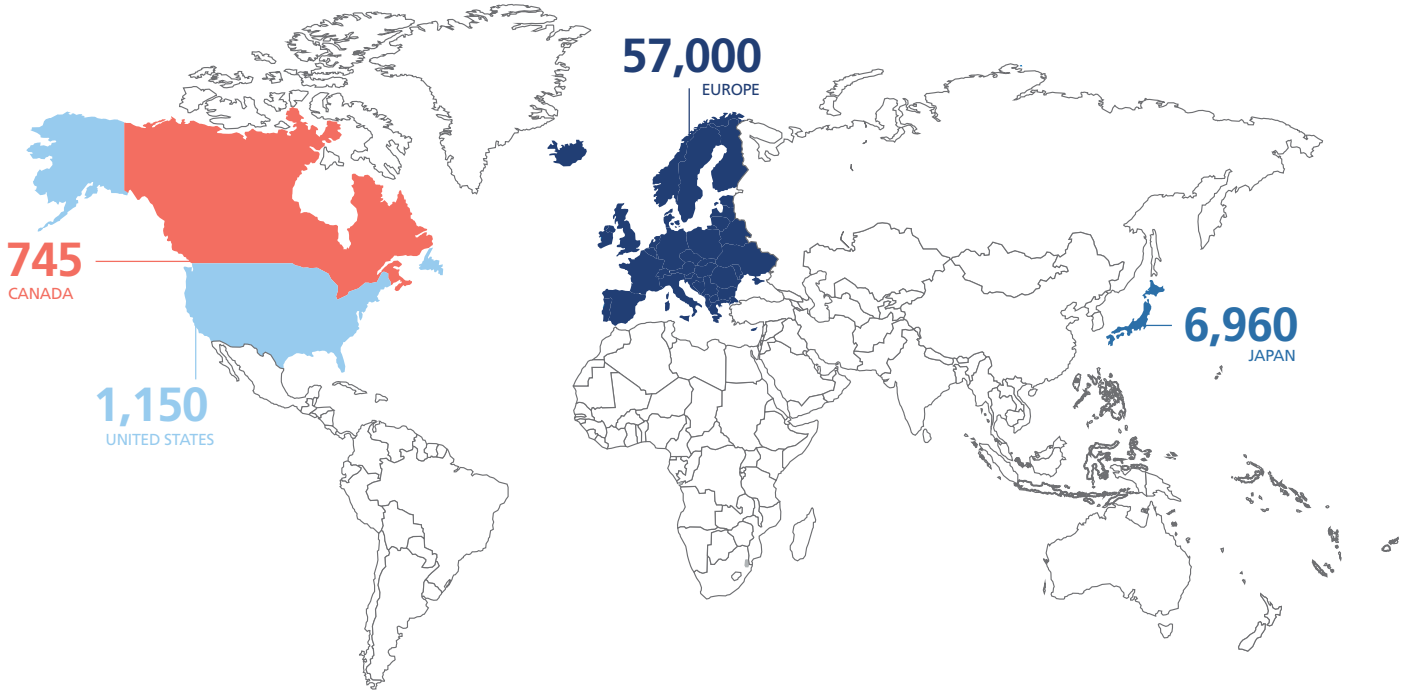
Japan

As of December 2022, there were 6,630 stores using transcritical CO_2 systems in Japan's commercial refrigeration sector, up from 5,800 stores reported in 2021. The majority were installed by convenience store operator Lawson, which had 5,028 stores using CO_2 outdoor condensing units (OCUs) as of December 2022 (more than one-third of their fleet of 14,656 stores). 7-Eleven Japan is another significant convenience store user of transcritical CO_2, with 215 outlets using the technology as of March 2021. In the supermarket sector, there were an estimated 300 stores using transcritical CO_2 refrigeration as of December 2022.

As of December 2022, there were an estimated 330 industrial sites (mostly cold storage) using transcritical CO_2 installations in Japan's industrial refrigeration sector, up from 260 reported in 2021.

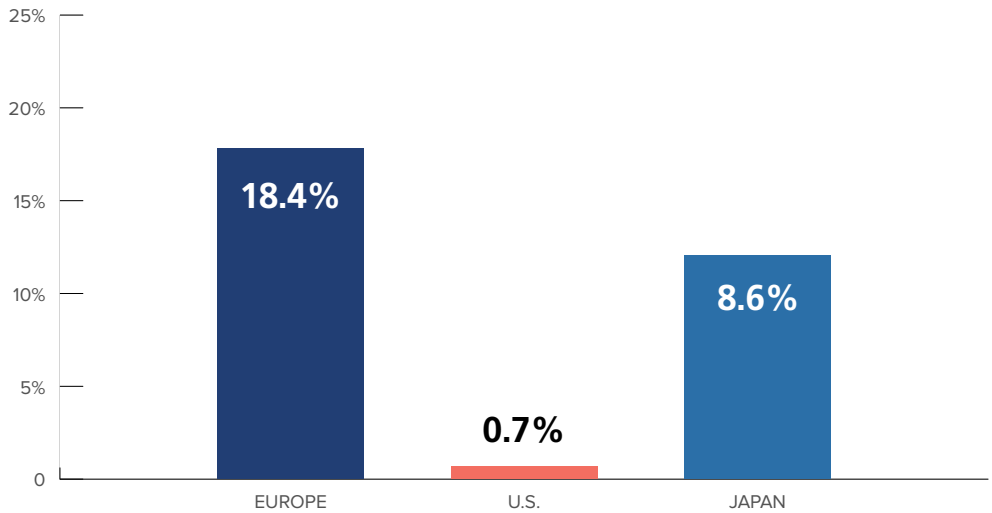
Transcritical CO_2 Installations in Major Regions

(stores and industrial sites, as of December 2022)



Transcritical CO_2 Market Penetration in Major Regions

(supermarkets, grocery and convenience stores, as of December 2022)



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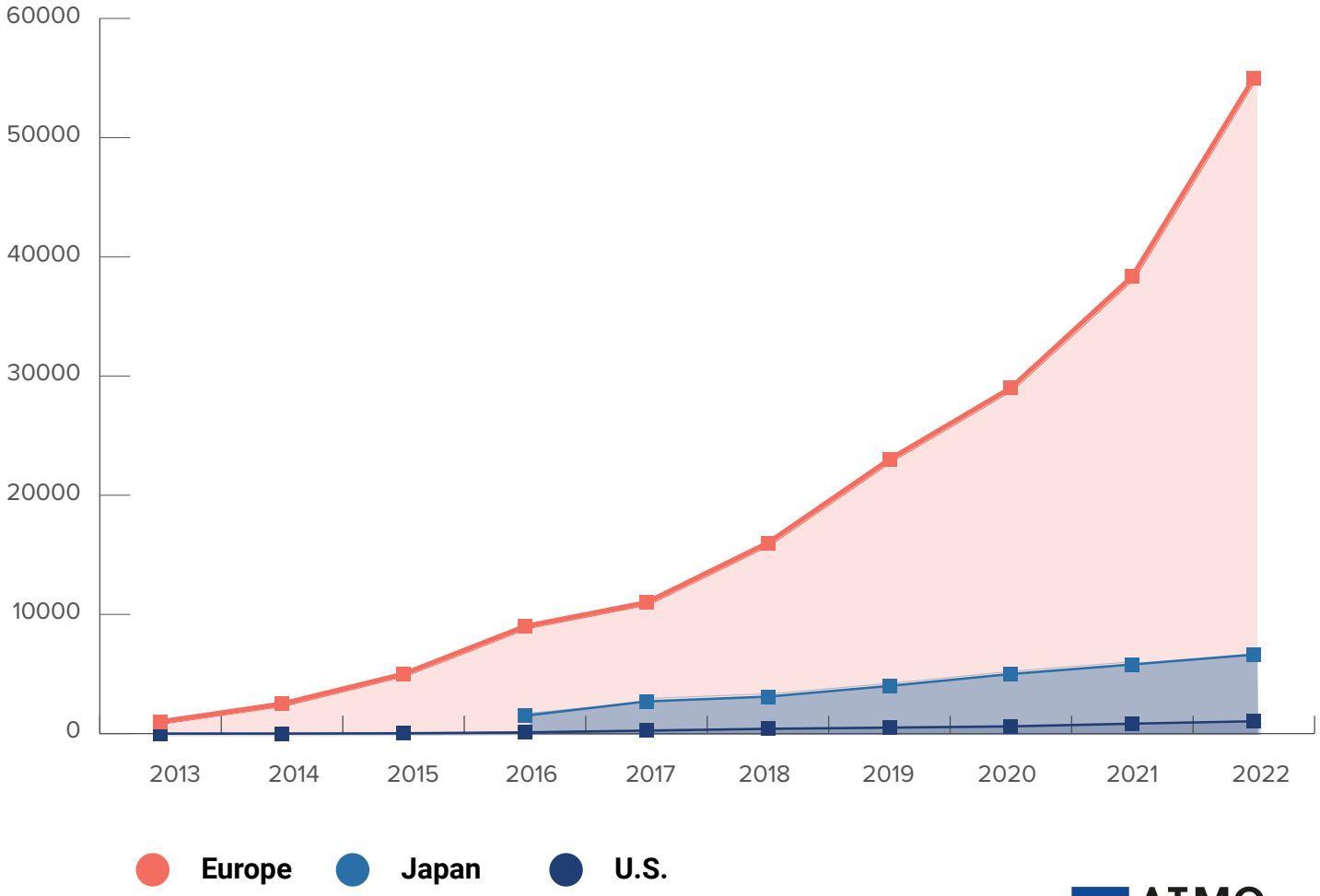
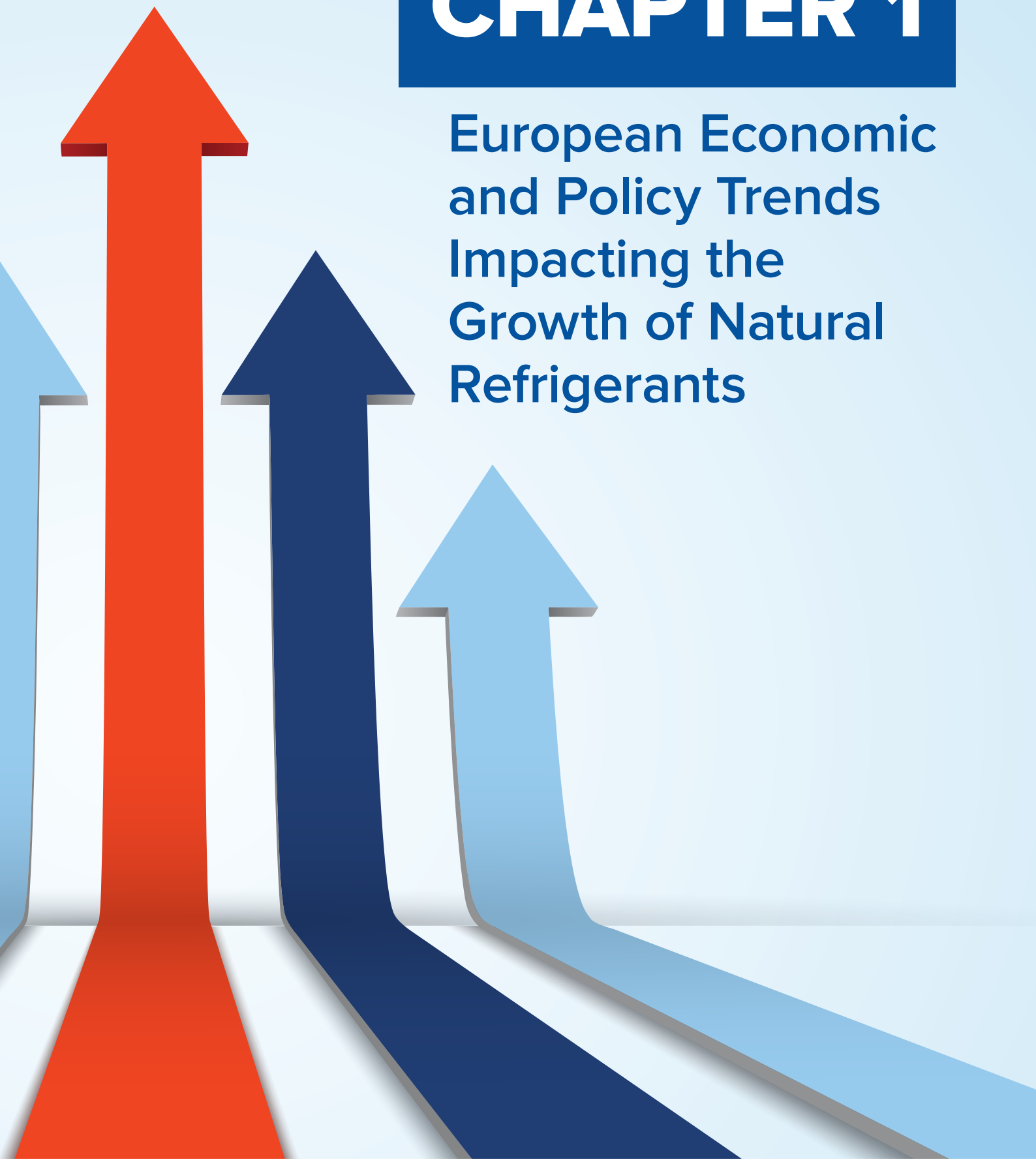
Transcritical CO_2 Installation Growth in Major Regions

(stores)



CHAPTER 1

European Economic and Policy Trends Impacting the Growth of Natural Refrigerants



1.1 The European Food Industry: Economic Outlook

The Impact of Ukraine Invasion

The widespread application of vaccinations and medical treatments for COVID-19 has enabled the return to some degree of normalcy in the European food retailing, storage and processing industries. Even as infection rates remain high, severe cases, hospitalizations and deaths have significantly diminished.

But COVID-19's impact on the supply chain continues to be a factor in many cases, as deliveries of components and ingredients continue at a snail's pace. This has generally caused delays, but not cancellations, of new refrigeration equipment and store construction.

In Europe, just as the COVID-19 pandemic had a huge impact on the food and refrigeration sectors in 2020 and 2021, the Russian invasion of Ukraine had a pronounced effect in 2022. The impact on the food sector has an accompanying effect on the purchase of refrigeration equipment.

As a single market, the EU has been able to ensure food security for its citizens and guarantee income support for European farmers, according to an analysis by the European Council.[1]

However, the reduction in imports of certain commodities from Ukraine, notably maize, wheat, rapeseed, sunflower oil and meal, has impacted feed prices for the EU's food industry.[2] This has led to higher market prices on top of existing inflationary trends, raising concerns about the affordability of food.

Overall inflation in the European Union reached 5.6% in January 2022, while food prices rose 3.5%, trends then accelerated by the Russian invasion of Ukraine, according to McKinsey & Company and EurocCommerce for retail and wholesale, "The State of Grocery Retail 2022 – Europe."[3] By July, overall inflation rose to 8.6%[4] and in November food inflation jumped to 17.9%.[118] Inflation causes grocery retailers' costs to increase and consumers' disposable income to shrink, resulting in lower margins for grocers. This means less ability for grocers to purchase equipment.

"Consumers are expected to trade down and shift their spend to retailers with strong private-label offerings in the entry-price range," said the McKinsey. report

Another issue stemming from the war is the move by Russia to restrict natural gas shipments to Europe, causing higher energy prices and worries about a recession, even as the economy is beginning to recover from the COVID-19 pandemic. The continent relies on Russian natural gas, and higher energy prices were flowing through to factories, food costs and fuel tanks.[4]

Molkerei Berchtesgadener Land, a large dairy cooperative in the German town of Piding outside Munich, stockpiled 200,000L (44,000gal) of fuel oil so it can keep producing power and steam for pasteurizing milk and keeping it cold if electricity or natural gas to its turbine generator is cut off.[4] It's a safeguard for 1,800 member farmers whose 50,000 cows produce a million liters (264,172gal) of milk a day.

Compounding rising energy costs is the spike in global temperatures, which is causing food retailers and warehouse operators to expend more energy keeping food at appropriately cold temperatures. This is also underscores the need for energy efficiency, and thus the use of efficient refrigeration systems that use natural refrigerants.

Grocery Retail

The European grocery retail market in 2021 was shaped by "the ongoing effects of the COVID-19 pandemic, the gradual reopening of the hospitality sector, the emergence of instant delivery (quick commerce) players and price inflation," according to the McKinsey & Company report.

Revenue for European "modern grocery retail" (supermarkets, hypermarkets, discounters and online grocery) dropped slightly (-0.1%) in 2021 compared to 2020, said McKinsey. The company noted that 2020 was a very strong year because of the stay-at-home trend caused by COVID-19. Compared to the pre-COVID year of 2019, European grocery revenues were up 11.4% in 2021.

Online grocery revenues continued to grow, by 8.8%, in 2021 compared to 2020; but compared to 2019, online revenues in 2021 increased by a spectacular 67.3%, again reflecting the impact of COVID-19.

Despite falling sales in brick-and-mortar formats and even higher declines in brick-and-mortar volume (unit sales), grocery retailers kept expanding their store networks, with available sales space expanding by 1.6%, said McKinsey. The biggest growth in space took place in small retail formats such as discounters (like ALDI, Lidl and Biedronka) at 4% and convenience stores at 3.8%. This in turn boosts investment in refrigeration tailored for small outlets, like CO2 condensing units and self-contained hydrocarbon cases.

But going into 2022, and even before the invasion of Ukraine, grocery CEOs expected market conditions to deteriorate. In McKinsey's State of Grocery CEO Survey, which included 57 European grocery CEOs, 60% of respondents said they believe market conditions this year will be worse than in 2021. Top reasons for their pessimism include the shrinking size of wallet for grocery retail as restaurants reopen in many parts of Europe, increased price sensitivity and competition (including from a maturing online market), and rising inflation.

Wage increases, labor shortages, supply chain issues and new regulations in some markets are other factors that affect the outlook of CEOs. The top opportunity cited by CEOs is e-commerce and omnichannel offerings, which remain a key priority for many of them, the survey indicated. This points to where there are opportunities for natural refrigerant equipment.

Cold Storage

The cold storage industry has benefitted from the COVID-19 pandemic, according to AMA International, a Dutch mergers and acquisition specialist, which published an article about the cold storage industry on its website last July.[5]

Due to increased lead times and the challenge in maintaining the quality of the perishable products, companies are relying more on having a cold storage warehouse to improve a product's life cycle, said AMA. Fish and meat suppliers fall into this category, followed by the dairy industry, pharmaceutical and processed food items.

In addition, rising health problems left consumers more focused on fresh food products, beverages, and drinks. For example, global milk production grew by 1.7%. "As the demand for perishable goods, food items, and beverages rise, the demand for cold storage increases," said AMA.

AMA saw third-party logistics providers, manufacturers and last-mile providers investing heavily in cold chain or cold storage worldwide, especially in Europe.

As a result, European cold storage facilities have grown in revenue from US$100 billion in 2020 to about US$125 billion in 2022, which is projected to double to US$200 billion by 2026, said AMA.

Not only will trade between the European countries act as a catalyst for cold storage, but also trade between EU and other countries like Viet Nam (one of the fastest growing economies) and India have developed cold storage corridors with European countries, said AMA.

Cold storage has also benefitted from the exponential growth in e-commerce. Retailers and wholesalers are forming a strategic alliance with third-party logistics providers to meet this demand. Having a cold storage facility at a micro-level increases the "last-mile experience" for the customer and improves market share, said AMA.

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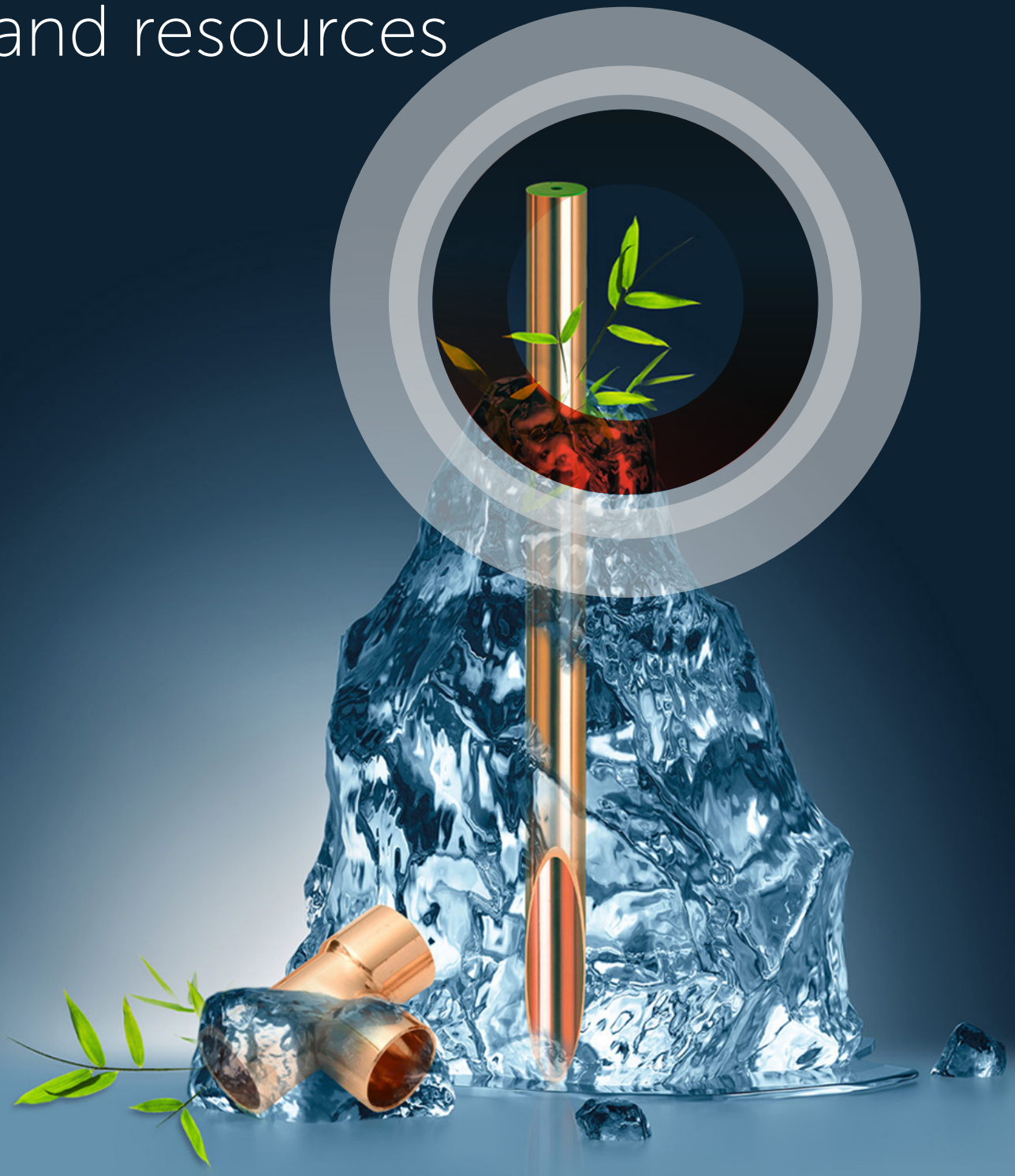

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In a June 2022 online article, "Beyond the distribution center," McKinsey & Co. points out that the emergence of online grocery shopping as a consequence of COVID-19 has led to the development of new fulfillment models that transcend traditional paradigms.[6] "Today we are in an environment with a higher prevalence of e-commerce shopping (30 percent higher penetration than pre-COVID-19), higher customer expectations when it comes to delivery speed, and higher availability of excess space within stores—which combined create an opportunity to evaluate new fulfillment models that move beyond the DC-centric model of the past," says McKinsey. "Today's customer requires greater agility and greater speed than ever before, beyond what central DCs are currently set up to deliver on their own."

McKinsey argues that this has led to the emergence of "three horizons of change" in retail-fulfillment operations: within the store, around the store and in the neighborhood.

Inside stores, retailers such as Target and Walmart are employing less productive and excess store space to fulfill online orders, says McKinsey. "Using stores as fulfillment centers allows retailers to ship from locations closer to customers, which in turn drives down delivery times and cost."

Q (quick)-commerce players are shaking up the grocery and convenience spaces by offering delivery within as little as 20 minutes, notes McKinsey. These players, such as Gorillas, which launched in May 2020 in Berlin, focus on a small market radius by locating "dark stores" or satellite stores near concentrated areas of demand.

While still a new and largely untested market, Q-commerce "is on a growth trajectory," says McKinsey. and with that growth comes a shift in the traditional distribution center model. While the DC-based fulfillment model focuses on locating a few large centers strategically across a region, Q-commerce operators put multiple micro-fulfiiment centers in a single area.

Real estate analysts CBRE suggests that the micro-level demand for cold storage will increase to US$100 million in the next five years, helping e-commerce take 21.5% of grocery revenues by 2025.[7]

With the rise in online grocery shopping, retailers must focus on having their own cold storage property or outsource the operation. Retailers try to place warehouses and storage facilities closer to stores. However, this can be a challenge in an urban setting
.

Food Processing

The food processing industry is highly developed in Europe in 2022 with 294,000 firms, representing 15.2% of all European industry and generating €1.1 billion (US$1.2 billion), according to data provided by the SIAL trade show.[8]

The food and drink industry is the EU's biggest manufacturing sector in terms of jobs and value added, says the EC.[9] It's also an asset in trade with non-EU countries. In the last 10 years, EU food and drink exports have doubled, reaching over €90 billion (US$89 billion) and contributing to a positive balance of almost €30 billion (US$29.7 billion).

EU food legislation is highly harmonized, and the sector benefits significantly from the opportunities offered by the EU Single Market, said the EC. At the same time, however, the sector faces certain challenges in both international and European markets.

"The European Commission is working to improve the competitiveness of the EU food sector and the functioning of the Single Market for food," said the EC. "It also strives to create new trade opportunities for food and drink products, through various trade negotiations and dialogues with third countries."

Revenues of European Cold Storage Facilities

2020 US$100 billion

2022 US$125 billion

2026 (projected) US$200 billion

Source: AMA International, July 4, 2022, "Growing Importance of Cold Storage for European Markets," https://bit.ly/3RAidCe

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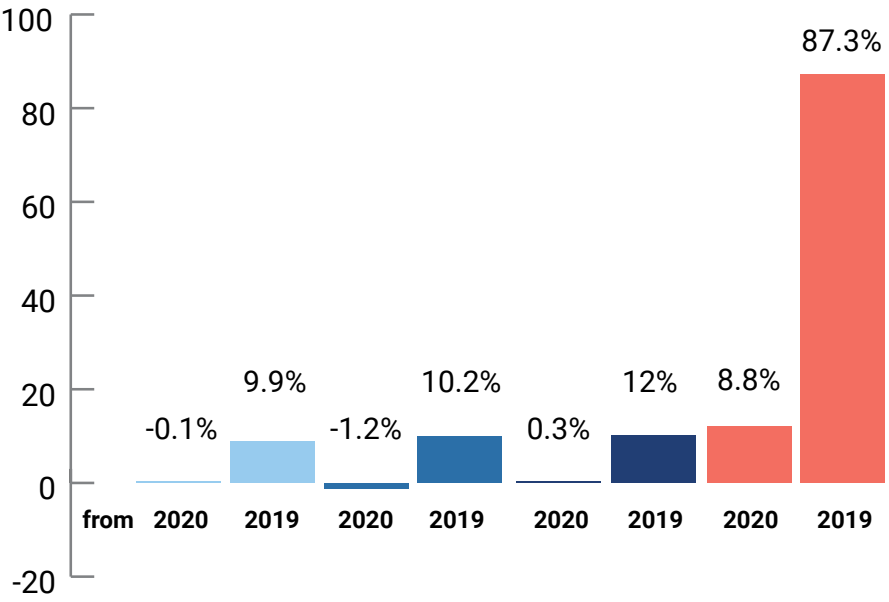
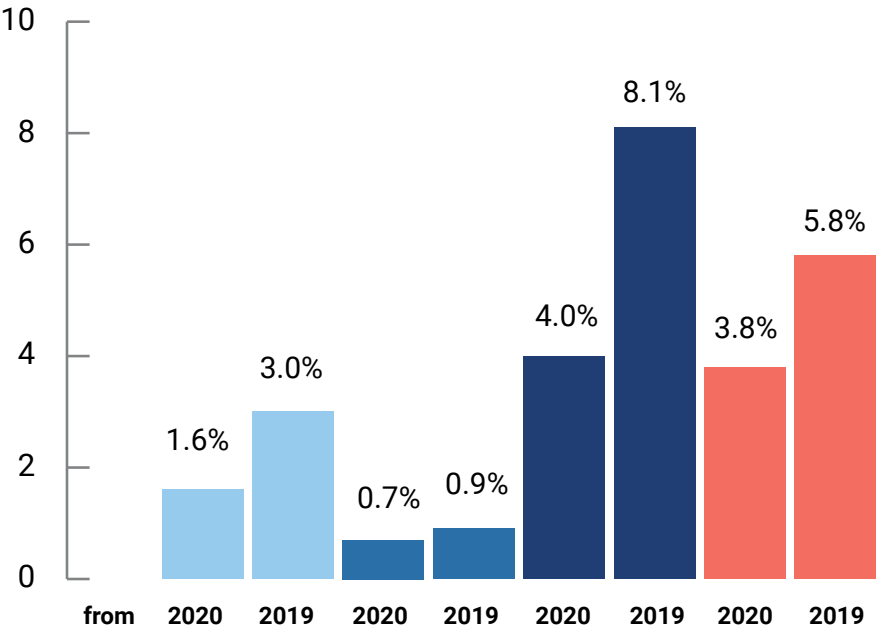
Revenue Growth in 2021, European Food Retail

- **Modern Grocery Retail***
  -0.1% vs 2020
  9.9% vs 2019
- **Supermarkets**
  -1.2% vs 2020
  10.2% vs 2019
- **Discounters**
  0.3% vs 2020
  12% vs 2019
- **Online Grocery**
  8.8% vs 2020
  87.3% vs 2019



Sales Space Growth in 2021, European Food Retail

- **Modern Grocery Retail***
  1.6% vs 2020
  3.0% vs 2019
- **Supermarkets**
  0.7% vs 2020
  0.9% vs 2019
- **Discounters**
  4.0% vs 2020
  8.1% vs 2019
- **Convenience Stores**
  3.8% vs 2020
  5.8% vs 2019



Source: "The State of Grocery Retail 2022 - Europe," by McKinsey & Company and EuroCommerce for retail & wholesale, https://mck.co/3M5F2fI

*Consists of hypermarkets, supermarkets, discounters and online stores.

1.2 Fit for 55

On July 14, 2021, the European Commission (EC) launched a package of 13 legislative proposals aiming to reduce the bloc's CO_2e emissions by 55% in 2030 (up from 40%) compared to 1990 levels. Included are several proposals that would affect the heating and cooling industry.[10]

The package, dubbed "Fit for 55," became part of the European Green Deal, first published at the end of 2019. The increased commitment improves the EU's contribution to the Paris Agreement and will also help the bloc reach its 2050 Climate Neutrality target.

Some of the HVAC&R-related proposals in this package include:

- Revision of the Energy Efficiency Directive: In 2012, the EU set a target to increase energy efficiency by at least 32.5% by 2030, with an interim target of 20% by 2020. These targets are currently not binding, but the new proposal would make them so.
- Carbon Border Adjustment Mechanism: A new proposal with the aim to restrict environmental dumping, or carbon leakage, by companies relocating production facilities outside the bloc in search of lower production costs.
- Revision of the Renewable Energy Directive: A proposal that would introduce higher minimum levels of renewable energy to be used in buildings. Currently renewables are about 20%; that will have to increase to around 38–40%. The revisions also look at the definition of which energy sources would qualify as renewable.
- Reform of the EU Emissions Trading System: The EC is planning to adjust the total cap to meet the 55% reduction targets, whereas the old cap was set for 40% reduction targets.

Any legislation aimed at reducing emissions is set to benefit the natural refrigerant sector, which offers drastically reduced direct emissions as compared to many fluorinated gases currently in use.

1.3 EU F-gas Regulation

The EU's F-gas Regulation is landmark climate legislation for transitioning away from fluorinated gases such as HFCs towards more climate-friendly alternative solutions such as natural refrigerants. Seven years after the implementation of the updated F-gas Regulation, it is now being updated again.

The first F-gas Regulation, adopted in 2006, stabilized f-gas emissions in the EU at 2010 levels. This was replaced in 2015 by the current EU F-gas Regulation (N517/2014), aimed at strengthening already-existing measures and introducing new changes with the goal of cutting f-gas emissions by two-thirds (of 2014 levels) by 2030. Separately, on September 27, 2018, the EU ratified the Kigali Amendment, which added HFCs to the Montreal Protocol's list of controlled substances, beginning a global phase down of HFCs that the EU was already pursuing through its legislation.

The current F-gas Regulation limits the sale of f-gases, bans their use in certain new equipment when alternatives are available, and requires equipment checks to prevent leakage during use and at end of life. The legislation also stimulates innovation, green growth and jobs by encouraging the use of climate-friendly cooling technologies. But thus far, only limited sectoral bans on HFC equipment have been included in the F-gas Regulation, failing to address the remainder of the HVAC&R sectors.

However, as of January 1, 2022, the F-gas Regulation banned use of new commercial systems with a capacity above 40kW (larger systems) that employ a refrigerant whose GWP exceeds 150. That will rule out nonflammable HFO blends like R448A or R513A, while still allowing A2L (slightly flammable) blends such as R454C. It will also support natural refrigerant adoption in larger commercial systems. The same is true for plug-in cases using hermetically sealed compressors, for which the regulation also banned refrigerants with a GWP higher than 150 starting in 2022.

EC's Proposed F-gas Regulation

The European Commission (EC) on April 5, 2022, released its long-awaited proposal updating the EU F-gas Regulation with measures to further clamp down on HFC use in the EU, opening up opportunities for natural refrigerants.[11]

Key parts of the proposal include accelerating the HFC phase down from 2024 onward – which would reduce HFC use to 2.4% of 2015 levels by 2048 – and improving enforcement and implementation. The F-gas Regulation proposal would abolish certain exemptions and bring the EU's HFC phase down fully into line with the Montreal Protocol's Kigali Amendment.

The proposed regulation would also, as of January 1, 2027, ban split air-conditioning and heat pump equipment with a capacity of more than 12kW (3.4TR) that uses f-gases with a GWP of 750 or greater. This ban would include industrial systems that could be replaced by natural refrigerant-based systems.

In regard to heat pumps, the proposal notes that any heat pump equipment with f-gases that is put into operation today will lead to direct GHG emissions for many years into the future due to leakage, necessary servicing with more f-gases and possible emissions when the equipment enters the waste stream. "Where possible this should be avoided, which is why specific product bans are included," the proposal adds.

The proposal would also increase the number of engineers qualified to handle climate-friendly equipment in Europe; EU member countries would be required to expand their certification and training programs to cover climate-friendly technologies that replace or reduce f-gas systems.

The F-gas Regulation proposal would amend a 2019 directive and repeal the 2014 version of the F-gas Regulation.

The EC considered suggestions by external consultants in developing the proposal. The results of this assessment were presented in May 2021.

Along with the proposed F-gas Regulation, the EC also released a proposed update to the regulation of ozone-depleting substances (ODS). Both proposals are now being negotiated by the Council of the European Union, the European Parliament and the EC in a process that will last until late 2023.

"For decades the European Union has had the world's most ambitious policy on fluorinated gases and ozone-depleting substances," said Frans Timmermans, the EC's Executive Vice-President for the European Green Deal. "While existing laws have been successful, science urges us to go further and faster now."

In a nod to natural refrigerant systems, Timmermans added, "Making climate-friendly technologies more widely available will help us reach the EU's long-term climate goals and encourage countries outside Europe to reduce their f-gas and use of ozone-depleting substances too."

Greater reductions of CO_2e emissions

Under the f-gas proposal, the maximum amount of HFCs allowed to be placed on the EU market in 2024–2026 is 41,701,077 metric tons of CO_2e, compared to a 2015 baseline of 176,700,479 metric tons. The maximum allowed in 2027–2029 is 17,688,360 metric tons, a significant drop from the current allowance (about 30 million metric tons). The amount allowed from 2048 onwards in the proposal would be no more than 4,200,133 metric tons.

Thus the proposed F-gas Regulation would save the equivalent of 40 million tons of CO_2e emissions by 2030 beyond the expected reduction under current legislation, reaching total additional savings equivalent to 310 million tons of CO_2e by 2050, the EC said. This would reduce the potential climate impact of new HFCs in the EU market by 98% between 2015 and 2050. The previous iteration of the regulation had an 80% reduction over the same time period.

The EC said the proposal would also make it easier for customs and surveillance authorities to control imports and exports, cracking down on the trade of illegal f-gases and equipment. Penalties will also become "harsher and more standardized." The quota system will be "limited to genuine gas traders through stricter registration rules and the introduction of a fixed quota price," added the EC.

In addition, a broader range of substances and activities would be covered, and the procedures for reporting and verifying data would be improved.

Along with the proposed EU F-gas Regulation, the EC's new proposed regulation on ODS is also expected to contribute to the EU's climate objectives. With this amended version, the EC wants to prevent the equivalent of 180 million metric tons of CO_2e and 32,000 metric tons of ozone-depleting potential (ODP) emissions by 2050. Higher ambition, modernized management systems and improved monitoring and enforcement are the main amendments presented in the text.

Members Working on the EU F-gas Regulation

In July 2022, party groups in the European Parliament appointed Members of the European Parliament (MEPs) who will follow the development of the proposed EU F-gas Regulation in the coming months.[12]

Bas Eickhout, a Dutch representative from the Group of the Greens/European Free Alliance (EFA), will be the rapporteur (MEP appointed to report on proceedings) for the Committee on the Environment, Public Health and Food Safety (ENVI) in charge of drafting the European Parliament's position on the F-gas Regulation.

Eickhout, in his third term in the European Parliament, is Vice-Chair of the ENVI committee and has worked on the Parliament's position during the negotiations leading to the current version of the regulation.

Shadow rapporteurs within ENVI have also been nominated. These are MEPs from other political party groups that will work alongside Eickhout during the internal negotiations on the EU F-gas Regulation. They are Stelios Kympouropoulos from the European People's Party (Christian Democrats), Günther Sidl from the Progressive Alliance of Socialists and Democrats in the European Parliament (S&D), Ondřej

Knotekfrom Renew Europe, Danilo Oscar Lancini from Identity and Democracy (ID), Alexandr Vondra from the European Conservatives and Reformists (ECR) and Nikolaj Villumsenfrom the Left group in the European Parliament (GUE/NGL).

According to the Parliament's website, the Committee for Industry, Research and Energy (ITRE) will also release an opinion on the text that will be drafted within ENVI. The nominated rapporteur is Sara Skyttedal, from the Group of the European People's Party (Christian Democrats).

Manufacturers Call for More Ambitious Regulation

Europe's leading manufactures of natural-refrigerant-based systems are calling for greater ambition in the EC's proposed revisions for the EU F-gas Regulation, suggesting stricter GWP limits, product bans and compensation for environmental damage.[13]

The proposed revisions include new restrictions on certain refrigerants and equipment, such as banning split air-conditioning and heat pump equipment with a capacity of more than 12kW (3.4TR) that use f-gases with a GWP of 750 or higher, But some manufacturers don't think the EU F-gas Regulation proposal goes far enough.

According to Andreas Meier, Managing Director of German OEM TEKO, the regulation "should be more ambitious with restrictions on refrigerant GWP." He added, "If it's above 50, or above 10 [GWP], just leave it out."

Meier's remarks came during an interview with ATMOsphere Founder and CEO Marc Chasserot at the ATMO World Summit on March 30, 2022, ahead of the release of the EU F-gas Regulation proposal. When asked about the impending revisions, Meier pointed out that "European manufacturers are leading in natural refrigerants, so why would we want to take this strong argument away?"

Joachim Schadt, General Manager of German chiller manufacturer Secon, echoed Meier's sentiment, stating that "the rapid transition to natural refrigerants is not only a necessity in terms of climate policy, but also offers the EU economic region an excellent opportunity to secure its prosperity."

"I would like to see deletion of all exemptions for which there are demonstrably already marketable solutions with natural refrigerants," continued Schadt. "Companies like ours are already demonstrating that natural refrigerants can be used safely and efficiently in almost any refrigeration application."

TEKO's Meier also believes there's a need for stronger deterrents to high-GWP refrigerants, such as bans or taxation. While recognizing that the latter falls under national and not EU-level jurisdiction, Meier expressed concern that without such action, there will be no meaningful change. An example of such a tax can be found in Denmark.[14]

Schadt echoed Meier's call for stricter control on f-gases in the EU F-gas Regulation, stating that "there's no substitute for bans, as the illegal trade in refrigerants has already thwarted the current F-gas Regulation." While not being a particularly strong advocate of such an approach, Schadt says he sees "no other way forward, as we have unfortunately already lost far too much time in mitigating the effects of the climate crisis."

In addition to bans, Schadt has expressed an interest in legislation that "obliges the producers of refrigerants to pay in full for all environmental damage that is already demonstrably known today or for which there is already a reasonable suspicion." While many are proposing HFOs as an interim lower-GWP solution to aid the HFC phase-down, neither Schadt nor Meier support this approach.

"The exclusive consideration of GWP values is in any case a misguided approach," said Schadt. "This has already led to a shift towards refrigerants [like HFOs], which will cause even greater and more far-reaching environmental damage."

On the topic of HFOs, Schadt voiced the opinion that while this issue does not belong in the F-gas Regulation, the potential impacts of TFA – a by-product of some HFOs and HFCs – would require HFOs to be included in the EU's REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) Regulation, which works to protect human health and the environment from chemicals.

Other voices from around the industry

In addition to manufacturers, many other HVAC&R stakeholders have been expressing their views on the EU F-gas Regulation proposal since its release in April 2022.[15]

HVAC&R trade associations have voiced concerns that the proposed changes are too restrictive and threaten the competitiveness of European manufacturers, as well as EU decarbonization targets and heat pump deployment.

But many NGOs have warned that the proposal risks undermining Europe's efforts to meet important climate goals due to the continued use of harmful HFCs, which currently account for 2.5% of Europe's total greenhouse gas emissions. NGOs have also criticized the proposal for lagging behind market evolution. While the revision does abolish certain exemptions included in existing regulations, the ongoing permitted use of HFCs is said to "fall short," they believe.

The European Environmental Bureau (EEB) welcomed the greater ambition in the F-gas Regulation proposal but contended that much more can be done. "We are surprised to see that climate-harmful refrigerants will still be allowed in heat pumps and refrigeration in this revision, especially considering how much the market has evolved towards natural refrigerants," said Davide Sabbadin, Senior Policy Officer for Climate at the EEB.

"Fluorinated gas should be the exception, not the rule," he added. "Quotas should be only left for those applications where natural solutions are not yet available."

The "best-performing" heat pumps in the market "are now working with natural refrigerants with GWP below five," said the EEB.

The EEB also noted that in 2023 the European Chemical Agency (ECHA) is expected to consider regulating f-gases such as R134a and R1234yf under the REACH regulation.

Sabbadin's sentiment has been echoed by Clare Perry, Climate Campaign Leader at the London-based Environmental Investigation Agency (EIA), who fears that the inclusion of HFCs in the revised EU F-gas Regulation "will result in yet another lost decade of climate change action at a time when the world can least afford it."

However, for industry bodies such as APPLiA (Home Appliance Europe), there is a deep concern that the accelerated rate of the HFC phase down and new equipment bans will negatively impact the innovation and competitiveness of European manufacturers.

Heat pumps, a replacement for fossil-fuel-based appliances, are at the center of much of the disagreement over the f-gas proposal. This is especially so in light of the EC's plan (dubbed RePowerEU) to roll out 30 million heat pumps by 2030 to reduce reliance on Russian gas in the wake of the Ukraine war.

There is concern from NGOs that doing so without ensuring the heat pumps operate on natural refrigerants will lock in polluting technologies for decades to come.

"It is critical that the revised F-Gas Regulation includes robust measures to ensure these heat pumps do not lock in the use of HFC refrigerants, effectively pitting one piece of climate legislation against another," said the EIA's Perry.

"Climate-friendly natural refrigerants can cover a significant proportion of the heat pump market, so a double climate win is possible – if the Parliament and Council have the vision to make it happen," Perry added.

In opposition, trade associations are concerned that the newly proposed EU F-gas Regulation will slow down Europe's adoption of heat pump technologies and its transition towards a cleaner economy.

For example, the European Heat Pump Association (EHPA) stated that the lack of "sufficient" HFC alternatives and trained installers "will massively 'decelerate' the deployment of heat pumps and other heating and cooling solutions required to achieve EU's 2030 climate and energy, as well as geopolitical goals."

Meanwhile, the European Fluorocarbons Technical Committee (EFCTC), while applauding the proposal's provisions to improve phase-down enforcement, has strongly reiterated concern that "the earlier and more severe proposed phase down could undermine the goals of the RePowerEU Action Plan. The [proposed revisions] could potentially slow down the

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much-needed adoption of heat pumps in Europe as well as other energy-efficient technologies."

Folker Franz, Director General of the European Partnership for Energy and the Environment (EPEE), noted that the current EU F-gas Regulation quota cuts HFC use by 88% by 2030. "Our modelling shows that this will be just enough to install the needed 50 million new heat pumps by then," he said. "The EU would harm its own cause by further cutting the quota."

In July 2022, the European Economic and Social Committee (EESC), a key EU advisory body, released its opinion on the proposed EU F-gas Regulation, calling for a ban on all refrigerants with a GWP above five in new heat pumps, room air conditioners, chillers and refrigeration applications as of 2030.

The opinions of this body are taken into consideration in the negotiations between the EC, Council of the EU and Parliament. It thus has a key role to play in the EU's decision-making process.

The opinion was drafted by Kęstutis Kupšys, rapporteur on the F-gas Regulation and representative of the Alliance of Lithuanian Consumer Organisations. The opinion was adopted with 140 votes in favor, 1 against and 6 abstentions.

The EESC also calls for banning the use of high-GWP refrigerants (such as R404a), setting a 150-GWP cap across all technologies, promoting incentive schemes and public procurement for f-gas-free alternatives and helping EU Member States incentivize greener solutions with very low GWP refrigerants, free of f-gases where possible.

While the EESC welcomes the EC-proposed EU F-gas Regulation, it believes further ambition can be deployed to "maintain the global EU leadership in climate action." The Committee asserts that the revision of this regulation is a chance to "significantly reduce direct climate impacts by promoting natural solutions with a low global warming potential (GWP) instead of continuing to use hydrofluorocarbons (HFCs) with a high global warming potential."

The EESC also notes that it is "extremely important to promote shifting directly to the lowest-GWP f-gas-free solution, avoiding intermediate solutions. EU markets demonstrate that this is feasible, and the EU should lead by example."

The EESC also calls attention to the challenges of operating with "any kind of f-gases blends, even low-GWP ones," as they make recycling, reclamation, maintenance and servicing more complex.

In response to concerns that the EU's REPowerEU heat pump rollout will be hampered by the F-gas Regulation, the EESC labels them "unfounded, due to the increased production capacity of the industry, which will be mostly based on natural refrigerants."

The EESC adds that the "EU has a clear opportunity to make this an exemplary case in setting global green standards" and "to make sure that European businesses and households are not burdened with a climate-damaging stock of equipment for decades to come."

ATMOsphere, publisher of this report, last year released a report on the market for natural-refrigerant-based domestic heat pumps.[16]

The EESC's opinion also calls for negotiators to raise the fee applied to the sale of allowances (by a proposed €3 [US$3.06] per metric ton of CO_2e), suggesting that incomes can be benchmarked to support stakeholders in contributing towards more climate-aligned technologies. Finally, the advisory body supports the acceleration of training initiatives on HFC alternatives.

The EESC is the voice of organized civil society in the European Union and is a consultative body, where representatives of the bloc's socio-occupational interest groups and others can express their point of view on EU issues.

1.4 The U.K.'s Approach to F-Gases

After the U.K.'s exit from the European Union, many wondered how this change would impact the refrigeration, air-conditioning, and heat pump (RACHP) industry, especially in relation to f-gas regulations.

Starting December 31, 2020, EU law, including F-gas Regulation No. 517/2014, no longer applied to the U.K. However, the U.K. has said it will follow the EU's lead on revisions to the current EU F-gas Regulation and has also implied it may be willing to go even further in terms of ambition.[17]

Following Brexit, the U.K. Department for Environment, Food and Rural Affairs (Defra) has led the effort to draft the country's f-gas regulation. A new regulation, however, is not expected to come into force before 2024.

Defra and the U.K.'s Environment Agency have a website for f-gas regulations.[18] On August 3, 2022, the website updated guidance for applying for a quota to produce or import f-gas and to transfer and authorize an f-gas quota to another business.

The website published a list of f-gas incumbent quota holders and authorization managers in Great Britain (England, Scotland and Wales) for the 2021 to 2023 reference period. It also published how to import, export or manufacture equipment pre-charged with f-gas.

In June 2022, the U.K. Climate Change Committee (CCC) called for the U.K. government to "match or exceed" the level of increased ambition that will be adopted following the revision of the EU F-gas Regulation. This was one of the messages contained in the 2022 Progress Report to the U.K. Parliament. The report pointed out major gaps in the implementation of policy measures supporting the U.K.'s net-zero goals.

The report noted that the f-gas sector represented 3% (12Mt of CO_2e) of total U.K. emissions in 2020. Even if credible policies to reduce f-gases are in place domestically, the CCC called for "stronger international action on reducing f-gas emissions, including health services in other countries," referring to f-gases emissions released from the use of high-GWP HFCs in metered dose inhalers.

With regard to heat pumps, the CCC said, "Most heat pumps use f-gas refrigerants, which could become a significant source of f-gas emissions as heat pumps get rolled out across the U.K., unless the Government takes action to ensure that they shift to using non-F-gas refrigerants. Potential replacement refrigerants [to fluorinated gases] include propane and CO_2."

In May 2021, Defra held a stakeholder meeting to discuss plans to review the U.K.'s own f-gas regulation. Among the main takeaways from the meeting:

- The U.K. wants to align with new net-zero targets and ambitions.
- Defra will be working with customs to address illegal trade.
- The U.K. wants to propose "pragmatic, proportionate, and efficient" changes.
- The U.K. will set up sector-specific groups.
- Defra will see how the EU moves on f-gases to inform its proposal.
- Defra is aware of the trifluoroacetic acid (TFA) issue – HFO-1234yf degrades into TFA in the atmosphere – and is looking at existing and upcoming information.

The U.K. is motivated to be ambitious with f-gases to meet national expectations in regards to climate change. The nation also wants to be seen internationally as a leader in climate change and is counting on tackling f-gases as a way to reach this goal.

However, the U.K. is held back by being continuously compared to the EU, meaning it will have to be more ambitious than the EU if it wants to be seen as a global leader in climate change mitigation. In general, the U.K. appears to be more open to addressing specific issues such as air-conditioning or TFA where the EU is more hesitant.

If the U.K. decides to be ambitious with its f-gas update, it could pave the way for the EU to be more ambitious as well. As a minimum impact, it would force a shift away from climate-polluting refrigerants in the U.K., driving accelerated adoption of natural refrigerant systems.

1.5 Hydrocarbon Charge Limits

In 2019, the International Electrotechnical Commission (IEC) voted to increase the allowable charge of hydrocarbons like R290 in commercial self-contained cases from 150g to 500g, updating its IEC 60335- 2-89 standard. The next step is for individual countries and regions to adopt their own version of the IEC standard.

CENELEC, which is responsible for publishing European (EN) standards, published the 500g charge limit for hydrocarbons in commercial cases under EN 600335-2-89 in August 2022.

But the standard must still be included in the list of harmonized standards with the EU Machine Directive (MD) before it can be used as a reference by industry; this should happen in 2023.

In the EU, the EN 378 (ISO 5149) general standard allows hydrocarbon charges up to 1.5kg in display cases, if rigorous safety precautions are taken. This standard has been invoked by U.K. retailer Waitrose, which employs display cases that include between 300g and 1,000g of propylene (R1270) charge per circuit, depending on the size and type of fixture. Every installation using EN 378 charge limits has to have a specific risk assessment for each system location. A similar standard does not exist in the U.S. or Japan.

More hydrocarbon case adoption?

A higher charge limit for R290 in commercial cases has long been considered a way to increase adoption of hydrocarbon equipment in supermarkets; this is particularly aimed at larger cabinets that currently use multiple circuits to compensate for the 150g charge limit. Commercial ice machines will also benefit from being able to use a larger charge of hydrocarbons.

However, the commercial cabinet industry has already been able to install millions of hydrocarbon cabinets in stores around the world using the 150g charge limit. The majority of self-contained cabinets are covered with 150g.

Manufacturers of large cabinets will be able to use a single circuit with the larger charge rather than multiple circuits. However, the larger charge is contingent on an appliance being constructed to prevent a flammable refrigerant concentration to surround the appliance in case of a leak, as verified by the “Annex CC” test. As a result, some manufacturers prefer the multiple-circuits approach instead of a higher hydrocarbon charge in one circuit.

1.6 EU Energy Labeling and Ecodesign

Since January 1, 2019, suppliers (manufacturers, importers or authorized representatives established in the EU) have been required to register their products in the European Product Registry for Energy Labeling (EPREL).[19] In May 2022, the database was launched for public access and consultation.

One of the categories of appliances is refrigerators with a direct sales function, which includes supermarket cabinets, cabinets for scooping ice-cream, refrigerated vending machines, beverage coolers and ice-cream freezers.

As of March 1, 2021, the EU energy labels for refrigerating appliances with a direct sales function use a scale from A (most efficient) to G (least efficient) under Regulation (EU) 2019/2018.

For beverage coolers and ice-cream freezers, the labels also show the maximum acceptable ambient temperature.

The EU legislation on ecodesign was designed to improve the environmental performance of products by setting mandatory minimum standards for their energy efficiency. Rules on ecodesign for refrigerating appliances with a direct sales function apply from March 1, 2021, under Regulation (EU) 2019/2024.

An important change in the ecodesign rules, which took effect in 2021, was to further enhance the reparability and recyclability of appliances. This includes making spare parts more easily replaceable and ensuring that key parts, repair and maintenance information are available for end users and professional repairers for a minimum duration of seven to 10 years depending on the product.

On March 30, 2022, the European Commission proposed a new Ecodesign for Sustainable Products Regulation for more environmentally sustainable and circular products.[20] It was published with the Ecodesign and Energy Labelling Working Plan 2022-2024, which covers new energy-related products and updates and increases the ambition for products that are already regulated, as a transitionary measure until the new regulation enters into force.

A boost for natural refrigerants

The energy labelling and ecodesign requirement will force energy-inefficient equipment off the market, making space for best-in-class natural alternatives. This could increase the attractiveness of hydrocarbon-based refrigerants – such as R290 and R600a – in commercial appliances. There are already billions of hydrocarbon-based home fridges operating successfully with proven efficiencies.

1.7 HFC Taxes and Incentives

Another key policy influencer on natural refrigerants adoption is a tax on HFCs, which has been adopted in a number of European countries, including Denmark, Norway, Slovenia and Spain, and most recently in France.

The French tax, which was delayed from 2021 to January 1, 2023, targets all virgin (not recycled) HFCs and HFC/HFO blends. Applicable to producers and importers, the tax is set at €15 (US$15)/t$CO_2$e in 2023, rising to €30 (US$30)/t$CO_2$e in 2027. But, according to the adopted amended version, the tax would not take effect if the amount of HFCs placed on the market for the year 2022 is less than 10,170 Kt CO_2 equivalent.

France also adopted a plan to financially support HFC alternatives from January 1, 2019, until December 31, 2022, via an income tax discount. Companies were able to deduct from their taxable profit an amount equal to 40% of the original value of all new HFC-free refrigeration and air-conditioning equipment, including that based on natural refrigerants.

Since 2000, Denmark's imports and use of HFCs have decreased much faster than in the rest of the EU.14 This development is thought to be mostly due to an HFC tax adopted in 2001. The original HFCs tax in Denmark, DKK 150 (€20/US$22.3) per metric ton CO_2e, was increased by DKK 30 (€4/US$4) in July 2021.

In Norway many HFCs (imported or produced domestically) are taxed at the rate of €0.06 (US$0.06)/kg of CO_2e.[21] The tax applies to pure gases in bulk or contained in pre-charged appliances; it is not applied on recycled HFCs.

Germany, through its Federal Ministry of Economics and Climate Protection, has been promoting incentives for refrigeration and air-conditioning systems since 2008 as part of the National Climate Protection Initiative (NKI). Its most recent program, which began in Dec 2020 and runs through December 31, 2023, offers grants to commercial users of non-halogenated refrigerants in new stationary refrigeration and air-conditioning systems (including components and storage) and heat pumps as well as new vehicle air-conditioning systems in buses and trains.[22]

The grant is available to companies, non-profit organizations, municipalities, local authorities, special-purpose associations and private companies, schools, hospitals and church institutions.

Refrigeration systems in the low-capacity range (starting at 1kW/0.28TR) are included in the subsidy, as are systems in the higher performance range, which were previously excluded.

HFC taxes can be seen as a driver for natural refrigerant growth, since natural refrigerant solutions are not taxed. The taxes, in effect, level the playing field, helping to make first costs of HFC and natural refrigerant systems more comparable. Incentives can be a great promoter of natural refrigerant systems, as seen in Japan.

1.8 HFCs, HFOs and TFA May Be Restricted Under REACH

In a move with major implications for the European HVAC&R industry, five European countries – Germany, the Netherlands, Norway, Sweden and Denmark – announced on July 15, 2021, their intention to submit a joint proposal to restrict per- and polyfluoroalkyl substances (PFAS), including some HFC and HFO refrigerants, to the European Chemicals Agency (ECHA) under the REACH regulation.[23]

The restriction proposal is subject to "adoption of the final opinions" by ECHA's Committee for Risk Assessment (RAC) and Committee for Socio-economic Analysis (SEAC), before it can be adopted by the European Commission. ECHA will address the proposal in 2023.[109]

PFAS, which represent a group of over 4,700 "forever chemicals," are used to produce many consumer products, but exposure to PFAS has been linked to harmful effects on human health.

As defined by the five countries – following the definition of the Organisation for Economic Co-operation and Development (OECD) – PFAS cover a number of f-gases, including certain HFCs and HFOs that are used in HVAC&R applications. In addition, trifluoroacetic acid (TFA), which is a PFAS under the OECD definition, is an atmospheric degradation product of HFO-1234yf and HFC-134a.

According to the OECD, PFAS contains at least one CF2 (perfluorinated methylene group) or one CF3 (perfluorinated methyl group) in its molecular structure. Among the HFCs that the countries identified as being PFAS are R134a, R125, R143a and R152a. Some of the HFOs include R1234yf, R1234ze(E) and R1233zd(E).

The REACH regulation governs the registration, evaluation, authorization and restriction of chemical substances in the EU. While HFCs are separately regulated by the EU F-gas Regulation, HFOs are not.

The EC defines restrictions under REACH as "regulatory measures to protect human health and the environment from unacceptable risks posed by chemicals."[24] In addition, "restrictions may limit or ban the manufacture, placing on the market or use of a substance," the EC says. "A restriction can apply to any substance on its own, in a mixture or in an article, including those that do not require registration."

The f-gas industry in Europe has pushed back against the classification of HFCs and HFOs as PFAS. "HFCs, HFOs and HCFOs are a distinct subset and due to their properties are not commonly regarded as PFAS," says the European Fluorocarbons Technical Committee (EFCTC) on its website.[25]

CHAPTER 2

North American Economic and Policy Trends Impacting the Growth of Natural Refrigerants

2.1 The North American Food Industry: Economic Outlook

U.S. supermarkets and grocery stores increased revenues by 4.5% to US$811.5 billion in 2022.[26] In the U.S. convenience store sector, revenues grew by 1.8% to US$37.3 billion.[27] Meanwhile, in Canada, supermarket and grocery store sales increased by 2.9% in 2022 to $115.5 billion,[28] while convenience-store sales went up by 0.5% to $11.2 billion.[29]

According to McKinsey, over the past few years North American grocers have been able to increase their capital expenditures, which includes refrigeration, at an amount 1.3 times their historical levels, thanks in part to an influx of funding. Capital expenditure experienced a compound annual growth rate (CAGR) of 1.8% between 2010 and 2018, but this grew to 4.2% between 2018 and 2020, with venture-capital firms raising $10 billion for grocery start-ups in the first six months of 2021 alone.

In 2021, U.S. sales of refrigerated foods totaled over US$83 billion, for a year-over-year growth of 0.3%.[30] However, in 2022, in refrigerated storage, revenues grew by 4.9% to US$7.6 billion in the U.S.[31]

The growth of investment in cold storage construction was robust in 2022, noted Kurt Liebendorfer, vice president of refrigeration manufacturer Evapco. This was driven by the gains in stay-at-home food consumption and supply-chain disruptions during the COVID-19 pandemic, coupled with cold-storage under-capacity and an aging cold-storage infrastructure, he added. However, inflation and a slower economy has slowed cold-storage investment of late and prospects for 2023 are unclear.

Food and beverage manufacturers also invested heavily in new facilities, in addition to cold-storage development.

The growth of cold-storage and food processing facility construction in 2022 brought increased investment in natural refrigerant-based refrigeration systems, both transcritical CO_2 and low-charge ammonia, in both the U.S. and Canada.

The latest United States Department of Agriculture (USDA) figures on refrigerated warehouses in the U.S. covers 2021.[32] In that year, the total number of refrigerated warehouses was 904. There was about 17.4 million m^3 (0.61 billion ft^3) of usable cooler capacity, defined as spaces that maintain temperatures between 0 and 10°C (32 and 50°F). There were approximately 68.3 million m^3 (2.41 billion ft^3) of usable freezer capacity, defined as spaces that maintain temperatures of about –17.8°C (0°F) or lower.

Higher food prices

Fueled by historic rises in labor, freight, and commodities costs during the latter half of 2021, inflation sharply elevated food prices in North America in 2022. The average price of food in the United States increased 10.4% in the 12 months ended December after posting an increase of 10.6% in November, according to the latest inflation data published January 12, 2023, by the U.S. Labor Department's Bureau of Labor Statistics (BLS).[33] The annual increase was even greater – 11.8% – for food at home (grocery sales) but less – 8.3% – for food away from home.

However, helped by diminishing gasoline prices, overall inflation rates have eased, dropping in December to 6.5%, the sixth consecutive month of decline.[34] While still high, this marks a shift away from strong monthly price increases. Moreover, the yearly inflation rate is expected to drop to 3.2% by the end of 2023.

The economy has shown other positive signs, including a low unemployment rate (3.7% in December) and an increase in the consumer confidence index.[35] In addition, the Biden administration and the U.S. Congress have passed a slew of bills to improve the economy in the long term, including the infrastructure plan, the CHIPS and Science Act, and the Inflation Reduction Act (IRA), which includes a huge commitment to green energy and cost containment for some drugs under Medicare.

On the other hand, in a presentation at the FMI Energy & Store Development Conference last September, John Anton, Economics Director for HIS Markit, predicted a 50% chance of weak economic growth, a 45% chance of a mild recession and a 5% chance of barely better than baseline. He believes the U.S. Federal Reserve will risk a recession to stop inflation.

Other challenges remain, such as the improved but still-fragile supply chain. Disruptions to supply chains during the pandemic have increased out-of-stock rates by upward of 15%, compared with historical rates of 5 to 10%, notes McKinsey.[36] Supply chain issues have been attributed to a host of factors, including bottlenecks at ports, labor shortages, and huge, unanticipated spikes in consumer demand. While overseas vessel delays and container shortages should pass, labor shortages and the ongoing shift toward automation have been a long time in the making and will require a sustained commitment to resolve, McKinsey adds.

But Anton sees bottlenecks in supply chains improving, backlogs shrinking and delivery times shortening, with the number of shortages declining.

Consumer trends

McKinsey advises retailers to focus on a handful of trends: the rise of the value-conscious, healthier-eating consumer; elevated consumer expectations for omnichannel (online and in-store) shopping, with those shoppers spending two to four times more than the solely in-store customer; an increased emphasis on sustainability; strategic workforce planning and investment in tech and analytics; and the growing importance of ecosystems and partnerships. All of these trends will create opportunities for investments in natural refrigerant solutions.

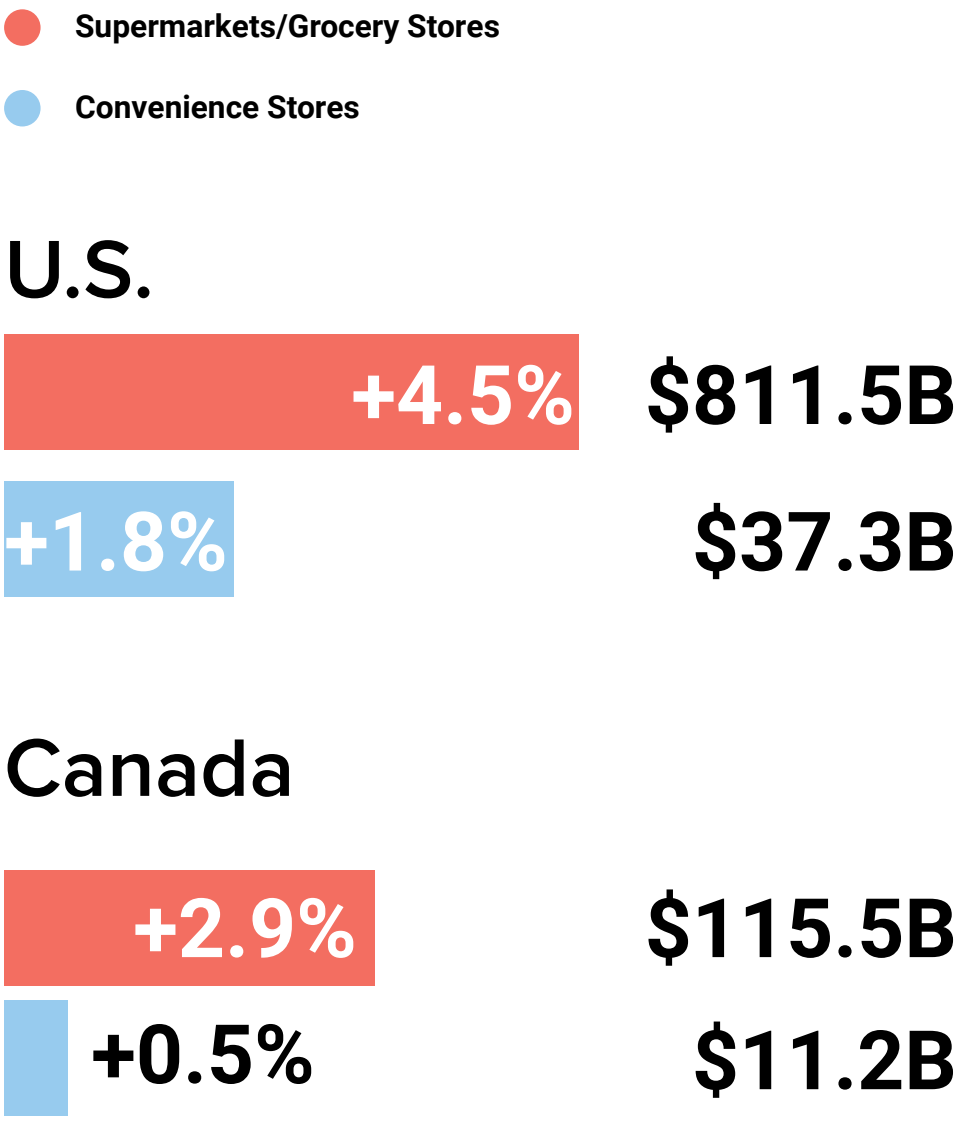
According to McKinsey, the North American food-at-home market, which had been slowly losing share to food away from home before 2020, has since surged 8.7% in sales, four times its historical growth rate. The move to food at home coincides with a growing emphasis on healthier eating. At the same time, consumers are making fewer trips and visiting a smaller number of stores.

Online grocery sales have grown nearly 60% since the beginning of the pandemic, though penetration rates have leveled off. Notably, McKinsey has found that North American consumers, in contrast to Europeans, prefer home delivery when grocery shopping online, marking a change from the preference for click and collect in 2020. Home delivery may even be handled by drones – something that was tested in 2021, according to FMI.

Consumers are balancing their emphasis on value with an interest in healthier foods, says McKinsey. About 40% of consumers expect to increase their focus on healthy eating and nutrition, including more regional and local goods, high-protein options and offerings that are free from certain ingredients, along with other naturally healthy options.

This emphasis on fresh foods supports having reliable, environmentally sustainable refrigeration. In a McKinsey survey, grocery CEOs largely expected consumers in 2022 to place a greater emphasis on sustainability across all dimensions and make different choices because of it. The emergence of more environmentally conscious consumers is forcing North American food companies to place a greater emphasis on sustainable operations, including refrigeration, and develop ESG targets.

North American Food Retail Revenues, 2022



Source: IBISWorld

2.2 The AIM Act

For many years, the U.S. Environmental Protection Agency (EPA) had the authority to phase out high-GWP HFCs. At the same time a voluntary EPA program, the GreenChill Partnership, worked with supermarkets to reduce HFC leaks and find natural refrigerant alternatives.

As of 2021, GreenChill encompassed 13,515 stores operated by 33 companies, with a combined leak rate of 12.9% (compared to an industry average of more than 20%).

On the regulatory side, the EPA's Significant New Alternatives Policy (SNAP) program[37] identified and evaluated substitutes for ozone-depleting substances by end-use. SNAP Rules 20[38] and 21[39] listed specific HFC refrigerants as unacceptable substitutes and identified acceptable alternatives.

But in August 2017, a U.S. District Court ruled in Mexichem Fluor, Inc., v. EPA that the agency could not compel companies that use HFCs as a replacement for ozone-depleting gases to then replace the HFCs with another refrigerant (like a natural refrigerant). The EPA reacted to this ruling by going further, allowing end users to replace remaining ozone-depleting refrigerants with HFCs. This set back the adoption of natural refrigerant systems in the U.S.

In response, 24 member states of the U.S. Climate Alliance[40] began addressing greenhouse gas emissions on a state level; 12 have adopted SNAP Rules 20 and 21, and another four are in the process of adopting them. California, New York and Washington have taken steps to regulate HFCs beyond adopting SNAP Rules 20 and 21.

Then, at the end of December 2020, as his administration was coming to an end, then-President Trump signed the American Innovation and Manufacturing (AIM) Act, part of a COVID-19 relief package, which authorizes the EPA to phase down HFCs via an allocation system, among other regulations. His successor, Joe Biden, has continued in this direction of positive climate action.

The AIM Act consists of three parts: phasing down the production and consumption (imports) of listed HFCs, managing these HFCs and their substitutes (including reclamation and leak management), and facilitating the transition to next-generation technologies.

The AIM Act brings the U.S. into alignment with the goals of the Kigali Amendment to the Montreal Protocol, which will slash HFC production and consumption globally for developed countries by 85% by 2036 to avoid up to 0.5°C (0.9°F) of global warming by the end of this century. On October 26, 2022, the U.S. joined the countries that have ratified the Kigali Amendment (currently 147).[41]

In September 2021, the EPA began fulfilling the first step of the AIM Act: establishing the allocation and trading of HFC allowances for 2022 and 2023. These allowances were designed to cut consumption (imports) and production levels by 10% of baseline. The baseline, based on data from January 1, 2011, through December 31, 2013, encompasses 303.89 MMTEVe (million metric tons of exchange value equivalent, which is equivalent to CO_2e) of consumption and 382.55MMTEVe of production.

On October 20, 2022, the EPA issued a proposed rule to implement the next step of the HFC phase down: a 40% reduction of consumption and production below the baseline level starting in 2024 and continuing through 2028.[42]

In regard to the transition to next-generation technologies, last December the EPA released a proposed rule setting a 150-GWP limit on the use of refrigerants in many new refrigeration systems, notably commercial and industrial systems, and a 700-GWP limit on the use of refrigerants in many applications, including new residential and light commercial air-conditioning and heat pumps.[43]

The proposal would ban refrigerants such as R134a, R404A and R410A in HVAC&R applications and require most new equipment being manufactured or imported to transition to more climate-friendly alternatives by 2025, as well as exported equipment beginning in 2026. The estimated additional emission reductions of the rule are up to 903 million metric tons of CO_2e by 2050, with net climate benefits of up to US$56.3 billion.

The EPA was guided in the new rulemaking by a series of petitions from NGOs and industry groups,[44] including one from the Environmental Investigation Agency (EIA),[45] to which ATMOsphere, publisher of this report, was a co-signatory. The rule will be finalized by October 7, 2023.

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In regard to reclamation of HFCs, the EPA released data and a draft report on October 17, 2022.[46,47] The Biden administration wants recovered HFCs from retired equipment "to offset the need for newly manufactured HFCs," and to be used "for federal facilities, equipment, and fleets."

Section 608 of the Clean Air Act was established to prohibit intentional venting of ozone depleting refrigerants (CFCs and HCFCs) and their substitutes (HFCs) while maintaining, servicing, repairing, or disposing of air-conditioning or refrigeration equipment.[48] Section 608 includes requirements related to:

- Technician Certification
- Refrigerant Recovery & Equipment Recycling
- Refrigerant Leaks
- Refrigerant Sales Restriction
- Recordkeeping
- Safe Disposal
- Reclamation
- Service Practices

In 2020, the EPA rescinded a 2016 Obama administration rule that had extended refrigerant leak repair requirements to HFCs and HFOs for equipment containing more than 50lbs (23kg) of refrigerant, including most supermarket and industrial applications.[49] The AIM Act gives the EPA the opportunity to restore the application of leak rules to HFCs and HFOs.

Overall, the AIM Act will force companies to move away from higher GWP refrigerants and embrace future-proof technologies such as natural refrigerants. Based on progress in Europe, reducing HFC allowances could rapidly increase the uptake of natural refrigerant technology – especially in commercial and industrial refrigeration. However, competition from HFO blends can be expected if these remain unregulated.

2.3 Hydrocarbon Charge Limits

The EPA has approved the use of hydrocarbons as refrigerants in residential fridges and commercial display cases, limiting the charge level to 150g.

However, in 2019, the International Electrotechnical Commission (IEC) voted to increase the allowable charge of hydrocarbons like R290 in commercial cases from 150g to 500g, updating its IEC 60335-2-89 standard. The next step is for individual countries and regions to adopt their own version of the IEC standard.

In the U.S., that step was started in October, 2021, when UL (Underwriters Laboratories) approved a second edition of the UL 60335-2-89 standard, including higher charge limits for hydrocarbon and A2L (less flammable) refrigerants.[50]

UL 60335-2-89 covers safety requirements for commercial refrigerating appliances and ice makers with an incorporated or remote refrigerant unit or motor-compressor. It incorporates the CSA (Canadian Standards Association) 60335-2-89 standard for the same equipment.

The new UL standard raised the charge limit in commercial plug-in display cases to 13 times the LFL (lower flammability limit) of a refrigerant – or 500g for propane (R290) – but only for open appliances (without doors). It raises the charge limit for closed appliances with doors and/or drawers to eight times the LFL of the flammable refrigerant (300g for R290).

A higher charge limit for R290 in commercial cases has long been considered necessary for wider adoption of R290 equipment in U.S. supermarkets. It will allow fewer compressors and condensing units to be used in cases, lowering costs and increasing energy efficiency.

The higher UL charge limits are contingent on an appliance being constructed to prevent flammable refrigerant concentration surrounding the appliance in case of a leak (releasable charge) as verified by the "Annex CC" test. Commercial appliances also must employ detection/mitigation controls to limit the releasable charge of the system.

In a separate but related development, the ASHRAE trade group has incorporated the new UL standard in ASHRAE 15, a standard for refrigeration safety.

But the U.S. Environmental Protection Agency still needs to follow suit by incorporating the updated UL standard in its SNAP (Significant New Alternatives Program) before the new limits can be implemented in the U.S. An EPA decision on the UL standard is expected during the first quarter of 2023.

State and local building codes would also need to adopt the new UL standard. This usually follows action by the International Code Council (ICC), which has adopted it in 2024 model codes, as has the National Fire Protection Association (NFPA). A number of states, including New York, Washington, California, Colorado, Maine and Texas, have already passed legislation to acccept the UL refrigeration standard once it is approved by the EPA. Some other states have already adopted the UL standard into their building codes.

In response to stakeholder interest in products that contain lower GWP refrigerants, the EPA has added new filters[51] to its online ENERGY STAR[52] product finders to highlight residential and commercial appliances that make use of lower GWP refrigerants, which in most cases are hydrocarbons.

2.4 U.S. EPA's Proposed Update of Risk Management Program

The U.S. Environmental Protection Agency (EPA) last August announced a proposed update of its Risk Management Program (RMP) rule, which regulates ammonia refrigeration, among other industries using hazardous chemicals.

Called the "Safer Communities by Chemical Accident Prevention Rule[53], the proposed rule is designed "to further protect vulnerable communities from chemical accidents, especially those living near facilities with high accident rates," the EPA said.

The proposed rule, the EPA added, "would strengthen the existing program and includes new safeguards that have not been addressed in prior RMP rules, such as enhanced employee participation and transparency for communities on safety decisions."

Highlights of the proposed rule include:

- Providing greater protections for communities living near RMP facilities, many of which are underserved and overburdened by pollution.
- Emphasizing the requirement for regulated facilities to evaluate risks of natural hazards and climate change, including any associated loss of power.
- Promoting environmental justice through increased availability of information for fenceline communities in their requested language
- Requiring safer technologies and analysis of alternatives for certain facilities with high accident rates.
- Advancing greater employee participation and opportunity for decision-making in facility accident– prevention requirements.
- Requiring third party audits for facilities with a bad track record of accidents.
- Enhancing facility planning and preparedness efforts.

The proposed rule comes in the wake of the recent checkered history of the RMP, which the EPA introduced in 1996. In January 2017, the "RMP Amendments Final Rule" issued new requirements for prevention, response, and public disclosure of information, but key provisions were paused, and most never went into effect.[54] Instead, in 2019, the "RMP Reconsideration Final Rule" rescinded or modified some of the measures in the 2017 rule.[55] The 2019 RMP rule was part of the Trump administration's efforts to roll back industry regulations.[56]

Five industry trade groups have co-signed a letter to the EPA objecting to certain provisions of the new RMP proposal.[57,58] The trade groups are: the American Frozen Food Institute, the Global Cold Chain Alliance, the International Institute of Ammonia Refrigeration (IIAR), the North American Meat Institute, and the Refrigerating Engineers and Technicians Association.

"IIAR does not agree with many aspects of the rule and believes that the current rules are generally sufficient for our industry," the trade group said in an email to its members on November 23 that publicly unveiled the EPA letter.

As they have in the past, the ammonia refrigeration trade groups objected strenuously in their letter to the proposed RMP rules regarding the need for third-party audits to be conducted by independent organizations.

2.5 U.S. EPA Urged to Broaden Definition of PFAS to Include F-Gases, TFA

The definition of PFAS (per- and polyfluoroalkyl substances)[59] used by the U.S. Environmental Protection Agency (EPA) should be broadened to include chemicals such as certain HFC and HFO refrigerants, as well as refrigerant byproduct trifluoroacetic acid (TFA), according to a scientist from the Green Science Policy Institute (GSPI).[60]

The scientist, Lydia Jahl, Science and Policy Associate for GSPI, presented this view via Zoom at a session on the impact of refrigerants on health, safety and climate at the ATMOsphere (ATMO) America Summit 2022.[61] ATMO America, held last in Alexandria, Virginia, was organized by ATMOsphere, publisher of this report.

The PFAS category comprises thousands of "forever chemicals" that are toxic, bioaccumulate in humans, animals and plants, and are extremely durable in the environment due to the extremely strong carbon-fluorine chemical bond.[62] They have been employed in hundreds of consumer products, including non-stick cookware, stain repellent, food packaging cosmetics and clothing. The ubiquity of PFAS has led to their being found in drinking water, among other places in the environment.

Two PFAS chemicals – PFOA, used in Teflon non-stick pans, and PFOS, an ingredient in 3M's Scotchgard stain repellent – were phased out in the U.S. under pressure by the EPA after the discovery of their health hazards, which include cancer, reproductive problems and endocrine disruption.[63]

Because of the difficulty of regulating thousands of individual PFAS chemicals, scientists have urged that PFAS be addressed as a class.[64] However, two differing definitions of this class have emerged.

A definition published by the OECD (Organization for Economic Co-operation and Development) describes PFAS as fluorinated substances that contain at least one fully fluorinated methyl or methylene carbon atom.[65] This definition is accepted by "leading PFAS scientists around the world," said Jahl. It is also used by the National Defense Authorization Act (NDAA) and several U.S. states, notably Maine, which aggressively regulates PFAS.

In Europe, five countries asked the European Chemicals Agency (ECHA) in 2023 to regulate PFAS under the OECD definition, including some f-gases and TFA.[66] The f-gas industry in Europe has pushed back against the classification of HFCs and HFOs as PFAS. "HFCs, HFOs and HCFOs are a distinct subset and due to their properties are not commonly regarded as PFAS," says the European Fluorocarbons Technical Committee (EFCTC) on its website.[67]

By contrast with the OECD definition, the EPA, through its Office of Chemical Safety and Pollution Prevention (OCSPP) defines PFAS more narrowly, saying it contains at least two adjacent carbon atoms, where one carbon is fully fluorinated and the other is at least partially fluorinated.[68]

The OECD's definition of PFAS includes certain f-gases like R134a (an HFC) and R1234yf (an HFO), as well as TFA, which is formed in the atmosphere by the breakdown of 100% of R1234yf and up to 20% of R134a. The EPA definition excludes f-gases and TFA, and many other harmful chemicals.

Because TFA and f-gases may have only one fluorinated carbon atom, they are called ultra-short-chain PFAS under the OECD definition. Long-chain PFAS such as PFOA and PFOS have eight carbon atoms. However, short-chain and ultra-short-chain PFAS share many of the characteristics of long-chain PFAS, and are even harder to remove from drinking water than long-chain PFAS.

"HFOs and TFA should be considered PFAS for their shared chemical structure, persistence and potential for harm," said Jahl. "There's no indication that ultra-short-chain [PFAS] molecules are safe. EPA's incomplete PFAS definition leaves room for harm." In Maine, the PFAS regulation has a reporting requirement for refrigerants considered to be PFAS, and plans to ban them in 2030 unless exceptions are made.

Jahl cited Linda Birnbaum, formerly the head of the National Institute for Environmental Health Sciences, who told the *Guardian* that the definition the EPA's toxics office uses is "a lot more like industry's" rather than like the definition used by the interna-

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tional scientific community.[69] "This highlights the importance of listening to the scientists who are actually studying these chemicals in depth," Jahl noted.
Jahl acknowledged that more toxicology data are needed "to be 100% certain" of TFA's potential effect on human health in water supplies and other places where it is collecting. "But we need that toxicity data before it would be wise to continue using TFA and products that results in TFA formation."

This is especially true, Jahl added, given the availability of natural refrigerants as "safer alternatives."

The chemical industry addressed the deposition of TFA in an October 2021 study by the Global Forum for Advanced Climate Technologies (globalFACT), which represents f-gas producers Chemours, Honeywell, Arkema and Koura (and equipment manufacturer Daikin).[70] The study concluded that "with the current knowledge of the effects of TFA on humans and ecosystems, the projected emissions through 2040 would not be detrimental."

But the study also acknowledged that "the major uncertainty in the knowledge of the TFA concentrations and their spatial distributions is due to uncertainties in the future projected emissions."

The EPA's more restrictive definition of PFAS has prompted criticism from myriad organizations in the past year. Last September, scientists from GSPI and several other groups (including the Environmental Working Group and the Natural Resources Defense Council) sent a letter to EPA Administrator Michael Regan urging the agency to use the OECD's definition of PFAS, which they called "scientifically sound and consistent with definitions that have been included in federal and state laws regulating PFAS."[71]

The letter also noted that the EPA's definition excluded many HFC and HFO refrigerants as well as TFA, which "poses risk to human and ecological receptors." The scientists pointed out that TFA has been recognized as a PFAS by the California Department of Toxic Substance Control, among others.

U.S. legislators have also weighed in. In November 2021, Representatives Deborah Ross (Democrat from North Carolina) and Nancy Mace (Republican from South Carolina) introduced the PFAS Definition Improvement Act (HR 5987), which would adopt the OECD definition of PFAS.

Last year, in a suit against the EPA in April, Public Employees for Environmental Responsibility (PEER), a Washington, D.C.-based NGO, alleged that the agency was "withholding documents explaining why it has adopted an exceedingly limited definition of [PFAS]."[72]

EPA subsequently released more than 2,500 pages of documents, but in June 2022 PEER said in a statement that it found "no scientific basis" for the EPA's working definition of PFAS, and "no reasons given for excluding thousands of chemicals included in State definitions." PEER added that it will challenge in court redactions in the EPA's documents that "may mask the scientific basis" for its PFAS definition.[73]

TFA accumulation

In her presentation, Jahl cited a number of studies finding growing amounts of TFA in the environment, which she attributed to "the broad use of HFCs and HFOs that react in the atmosphere to cause TFA formation."

Examples of the growth of TFA in the environment include a 17-fold increase in China groundwater,[74] a 10-fold increase in Canadian Arctic ice,[75] and an increase in plant material in Germany.[76] The growth in the Arctic is particularly notable since "there is no direct use of HFOs or TFA in the Arctic," Jahl said.

Other studies she mentioned found TFA in 89% and 96% of drinking water samples in Denmark[77] and Germany,[78] respectively, as well as "in high concentrations" in more than 90% of blood serum samples in China[79]. Another study, she noted, found TFA in beer and tea at concentrations of 6ppb (parts per billion) and 2ppb, respectively.[80]

The German Environment Agency (UBA) has set a "health orientation value" of 60mg/L (60ppb) and a precautionary measures value of 10mg/L (10ppb) for drinking water, noted David Behringer, Project Manager for Öko-Recherche, a German environmental consultancy, who participated in the impact of refrigerants session with Jahl.

In his presentation, Behringer described a study he participated in that found TFA concentrations in rainfall across Germany had increased three to five times compared to studies done more than 20 years earlier.[81]

While a significant generator of TFA, f-gases are not its only source, said Behringer. TFA is emitted directly from its manufacturing process (for lab use, for example) and is the degradation product of many herbicides and pesticides. “No one knows exactly how those sources contribute to the TFA in the environment.”

However, added Behringer, the continued use of HFO-1234yf in mobile air-conditioning “could well result in a situation where in the future the RAC [refrigeration and air-conditioning] sector is the main contributor [of TFA].”

2.6 California's Ambitious Refrigerant Rules

In 2016, the California state government authorized its Air Resources Board (CARB) to oversee the reduction of HFC emissions. Four years later, the board voted unanimously to approve a sweeping regulatory proposal putting in place stronger restrictions on the use of refrigerants in HVAC&R applications than current rules.[82,83]

Led by CARB, California has been the most proactive U.S. state in regulating and pursuing further regulations of HFCs in an effort to cut emissions by 40% of 2013 levels by 2030, per the 2016 law, SB 1383. In 2018, California passed SB 1013, which adopted previously used federal bans on high-GWP HFCs (EPA SNAP Rules 20 and 21) and allocated funding for natural refrigerant systems.

The 2020 regulations expanded the state's refrigerant restrictions considerably. Starting in 2022, new equipment with more than 50lbs (22.7kg) of refrigerant – typically used by supermarkets and industrial facilities – has been required to use refrigerant with a GWP of less than 150. This applies to new stores and remodeled facilities with new refrigeration systems. A remodeled facility is defined as an existing building used for cold storage, retail food refrigeration, commercial refrigeration or industrial process refrigeration that has undergone replacement of 75% or more of its evaporators (by number) and 100% of its compressor racks and condensers.

The 150-GWP cap is expected to cut emissions reduction per facility by more than 90%, said CARB.

In addition, food retailers with 20 or more stores would need to comply with one of two options for existing stores: maintaining a weighted average refrigerant GWP below 2,500 by 2026, or reduce GWP potential (charge size times GWP) by at least 25% by 2026. All stores would need to have an average GWP below 1,400 or reduce GWP potential by 55% by 2030.

In existing non-retail facilities, new systems used for industrial refrigeration could use refrigerants with a GWP between 1,500 and 2,200.

The Environmental Investigation Agency (EIA), with support from 120 industry and other stakeholders, lobbied CARB regarding the GWP of refrigerant in new ice rink systems, and the agency agreed to lower the requirement to 150 GWP for new equipment (750 GWP in existing facilities).

California's regulations have helped drive considerable adoption of natural refrigerants, particularly transcritical CO_2 systems, in supermarkets.[84]

Last October, California built on its 2020 regulation by enacting SB 1206, aimed at the sale or distribution of bulk HFCs or HFC blends, and designed to increase the adoption of natural refrigerants.[85]

Under SB 1206, as of January 1, 2025, the GWP of refrigerants entering the market in California may not exceed 2,200. This would mean that R404A and R507, which are commonly used in commercial refrigeration systems, would no longer be permitted for sale. From January 1, 2030, the GWP limit will be reduced to 1,500, which would prohibit the distribution of R410A and HFC blends like R407A and R407C.

By January 1, 2033, the maximum GWP of refrigerants entering the Californian market must not exceed 750, banning the sale of refrigerants like R448A, R449A and R134a.

SB 1206 also requires CARB to publish a refrigerant plan by January 1, 2025. The plan must detail how the state's economy, by sector, will transition from HFCs to ultra-low or no-GWP alternatives – such as natural refrigerants like ammonia/NH_3 (R717), CO_2 (R744) and propane (R290) – no later than 2035. This plan must include details on incentives, workforce development, and a reclamation system to support the state's transition.

California has also allocated US$45 million in new funding to CARB to support the state's transition away from HFCs.[86] This funding will be split between two programs. US$25 million will go to the F-Gas Reduction Incentive Program (FRIP), and US$20 million will go to the Equitable Building Decarbonization Program.[87, 88]

Another bill, AB 209, directs the California State Fire Marshall to complete updates to state building codes for low-GWP alternatives by July 1, 2023.[89]

According to the EIA, SB 1206 is expected to accelerate emission reductions in existing cooling equipment using HFCs by encouraging faster retrofit and replacement with low-GWP alternatives and increasing demand for recovered and reclaimed refrigerants.

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2.7 New York State's Proposed Refrigerant Rules

Effective January 1, 2021, New York State adopted EPA SNAP Rules 20 and 21 prohibiting certain HFCs in specific stationary refrigeration and air-conditioning end-uses. New York aims to reduce 1990 greenhouse gas emissions 40% by 2030, and 85% by 2050.

The state has also initiated a new rulemaking under NYCRR Part 494 that proposes new GWP thresholds for new and existing facilities.[90] New refrigerant prohibitions and the introduction of a refrigerant reporting system, as well as incentives and demonstration projects, are also under consideration. Notably, New York, unlike the EPA or other states, uses a 20-year GWP value rather than the traditional 100-year GWP value. The state sees natural refrigerants as its best option for replacing HFCs, said Suzanne Hagell, New York State Department of Environmental Conservation, in a webinar sponsored by the North American Sustainable Refrigeration Council in October 2022.

2.8 Washington State's Proposed Refrigerant Rules

Effective January 1, 2020, Washington State, under HB 1112, adopted EPA SNAP Rules 20 and 21 prohibiting certain HFCs in specific stationary refrigeration and air-conditioning end-uses.[91]

Washington has also begun formulating new rules that will establish GWP thresholds for HFCs used in new equipment and create a refrigerant management program.[92]

The rules propose prohibiting refrigerants above 150 GWP in new stationary refrigeration equipment containing more than 50lbs (23kg) of refrigerant in food retail refrigeration starting January 1, 2025. The rules tie the effective date of new GWP caps to 24 months after the adoption of updated safety standards such as for hydrocarbons, noted Linda Kildahl, Washington Department of Ecology, in a webinar sponsored by the North American Sustainable Refrigeration Council in October 2022.

This rules are expected to be finalized in late 2023.

2.9 Canadian Regulations

Mexico and Canada ratified the Kigali Amendment in September and November 2017, respectively.

In Canada, the Kigali Amendment was followed by a phase down of HFC production and consumption that went into force on April 18, 2018.

This phase down began in 2019 with a 10% reduction of the baseline, leading up to an 85% reduction in 2036, in alignment with the Kigali Amendment.

The scheduled reduction of HFCs includes bans on refrigerants above a certain GWP in specific appliances. As of 2020, a 2,200 GWP cap was set for centralized refrigeration racks and condensing units, a 1,500 GWP cap for low-temperature stand-alone

refrigeration, and a 1,400 GWP cap for medium-temperature stand-alone units. In addition, as of 2025, a 2,200 GWP cap is set for mobile refrigeration, a 750 GWP cap for chillers and AC and a 150 GWP cap for domestic refrigeration.

Quebec has stricter GWP limits. Since January 1, 2021, the province has required refrigerants with a GWP under 150 for systems that use more than 50lbs (23kg) of refrigerant and employ more than 50kW of input power. Also as of that date, Quebec has had a GWP limit of 1,500 for systems with less than 50kW of input power.

The Canadian federal government has followed the U.S. EPA in requiring stricter safety rules for systems with more than 1,000lbs (454kg) of ammonia, thereby benefiting the adoption of low-charge ammonia systems. The Canadian Centre for Occupational Health and Safety (CCOHS) provides information on the safe handling of ammonia.

In addition, provincial authorities enforce safety regulations; for example, the Technical Safety British Columbia (B.C.), oversees the safe installation and operation of ammonia systems. Among other measures, Technical Safety B.C. requires all operators that detect a leak of ammonia to report it to the organization within 24 hours, in accordance with the provincial Safety Standards Act. Technical Safety B.C. inspects the equipment when it's installed, then does periodic assessments throughout the lifespan of the system.

Canadian provinces also require on-site supervision of ammonia facilities to varying degrees. In British Columbia, ice rinks with systems exceeding 50kW in capacity need to be supervised by a qualified person during rink operation.

In Canada, government incentives have supported the uptake of natural refrigerants. In particular the province of Quebec has put in place different public subsidy programs aiming at saving energy and promoting natural refrigerants as a replacement for R22.

Currently Quebec, through its utility Hydro-Quebec, offers a program to support the energy efficiency of facilities. Even if not strictly related to the use of natural refrigerants, this program could persuade end users to invest in natural refrigerants that demonstrate energy savings.

At the national level, the government will start to offer carbon offset credits this year for projects that cut refrigerant emissions.

2.10 Mexico

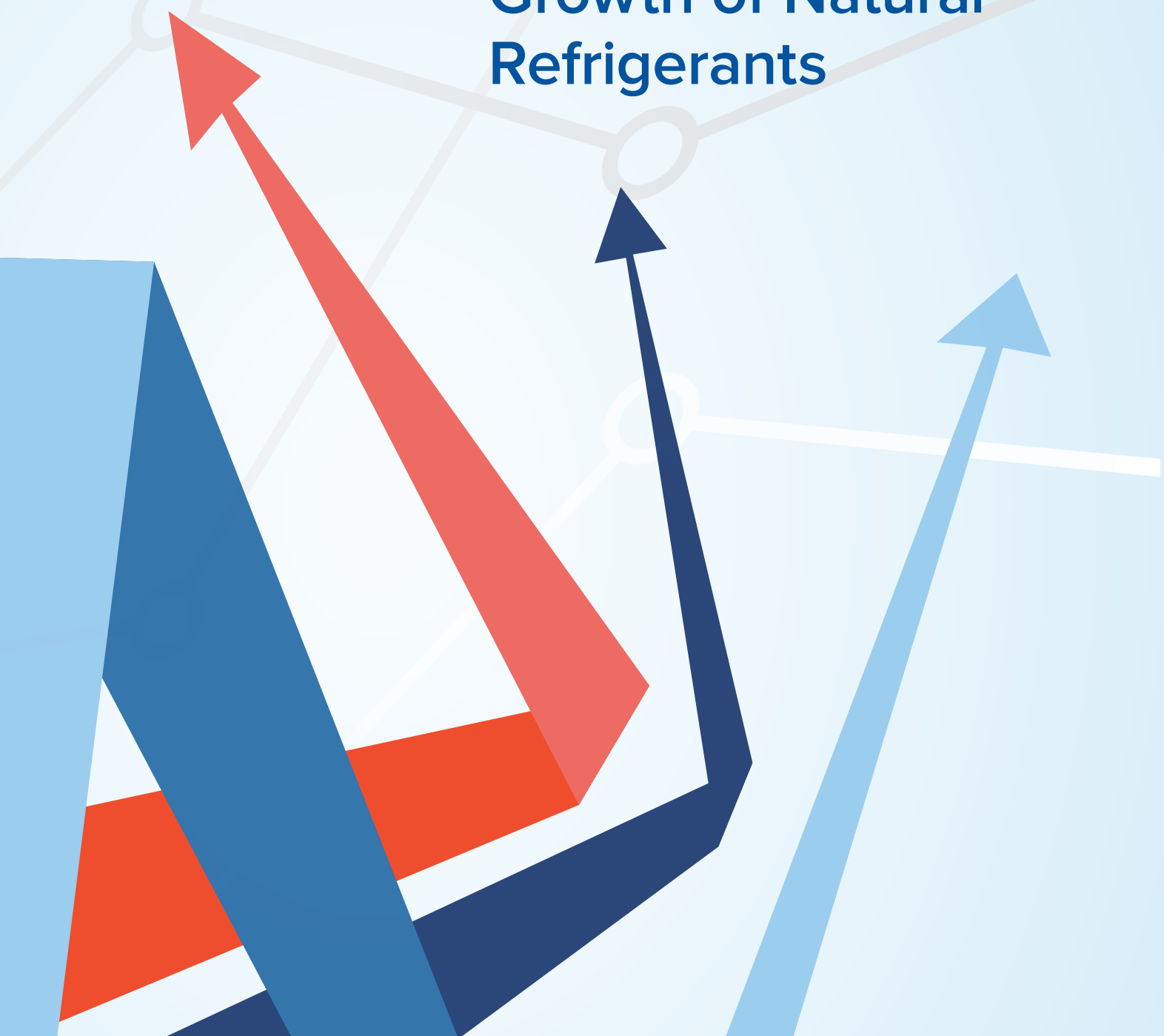
The ratification of the Kigali Amendment in Mexico occurred on September 25, 2018 and its promulgation decree was published in the Official Gazette of the Federation (OGF), on November 30, 2018.

As a developing (Article 5) country, Mexico uses as its HFC baseline the average consumption between 2020 and 2022 plus 65% of its HCFCs baseline. It is required to freeze consumption at that level starting in 2024, then cut consumption by 10% in 2029, 30% in 2035, 50% in 2040 and 80% in 2045.

Natural refrigerant adoption in Mexican supermarkets has been relatively uncommon since the first installation of a transcritical CO_2 system at a Casa Ley store in 2018.[93] Cold-storage operator Frialsa has also installed a number of ammonia/CO_2 cascade refrigeration systems.[94]

CHAPTER 3

Japanese Economic and Policy Trends Impacting the Growth of Natural Refrigerants



3.1 The Japanese Food Industry: Economic Outlook

Food and beverage sales at retail in Japan have been quite stable over the past decade. They were ¥45.15 trillion (US$345 billion) in 2020, slightly less than the previous year (¥45.36 trillion/US$346 billion) and just 3.5% more than the level in 2011.[95] Retail sales for Japan's 5,806 supermarkets came to ¥14.8 trillion (US$113 billion) in 2020.

Most transcritical CO_2 systems in Japan are installed at convenience stores such as Lawson. Also known as konbini, Japanese convenience stores sell a variety of fresh and packaged food as well as nonedible daily necessities. In 2021, the retail sales value of fast foods and daily foods sold at Japanese convenience stores, which total more than 50,000 locations, amounted to around ¥4.3 trillion (US$33 billion).[95] That year, fast foods and daily foods accounted for the largest sales share of commodities sold at Japanese convenience stores. Those sales peaked in 2019 at ¥4.6 trillion (US$35 billion) after a continuous increase throughout the preceding decade, and only dipped in the pandemic year of 2020.

The Japanese cold chain logistics market is expected to exhibit a growth rate of more than 2% during 2020–2025.[96] This is due to sales of ready-made meals and strengthening private-label products that promote traditional Japanese cuisine (bento and side dishes). The aging population in the agriculture sector is resulting in a reduction in the number of farmers and is one of the major reasons leading the Japanese population to shift to meat, seafood and frozen products.

Advances in the use of e-commerce to sell frozen and chilled goods will serve to accelerate cold storage development.[97] While cold storage facilities have traditionally tended to be constructed in the vicinity of seaports, locations closer to consumers are likely to be increasingly favored for new developments.

3.2 Refrigerant Phase Outs and Phase Downs

In 1988, Japan enacted the Act for Protection of the Ozone Layer, which established limits to production and consumption of R22 in Japan. A total ban on production and import of R22 has been in force since the beginning of 2020.

Japan's revised f-gas laws, which came into effect in April 2015, have created a greater impetus for the uptake of CO_2 systems within the commercial refrigeration sector.

On December 18, 2020, Japan ratified the Kigali Amendment to the Montreal Protocol, joining the global phase down of HFCs. The Amendment requires developed countries to take the lead on phasing down HFCs, starting with a 10% reduction in 2019 and delivering an 85% cut in 2036 (compared to a 2011–2013 baseline).

As f-gases are still used in an estimated 50.6% of cold storage facilities operated by members of the Japan Association of Refrigerated Warehouses (JARW),[98] there is an urgent need to consider switching to alternative systems, which is driving interest in CO_2. (JARW members represent about 80% of cold-storage capacity in Japan.)

On the whole, progress toward natural refrigerants is slow. This is because Japan's f-gas laws focus on the life cycle of refrigerants and introduce targeted years and targeted average GWPs for several HVAC&R sectors that are in some cases very unambitious in comparison to the EU F-gas Regulation. For example, condensing units in the commercial refrigeration sector have a targeted weighted average GWP of 1500 by 2025. Such a high GWP target doesn't incentivize the majority of local manufacturers to invest in natural refrigerants; they instead gradually shifted to HFO blends like R448A to comply.

On the other hand, the industrial refrigeration sector has a targeted weighted average GWP of 15, so here the move to natural refrigerants (especially NH_3/CO_2 and CO_2) is clear, along with some limited competition from HFOs.

3.3 Natural Refrigerant Subsidy Scheme

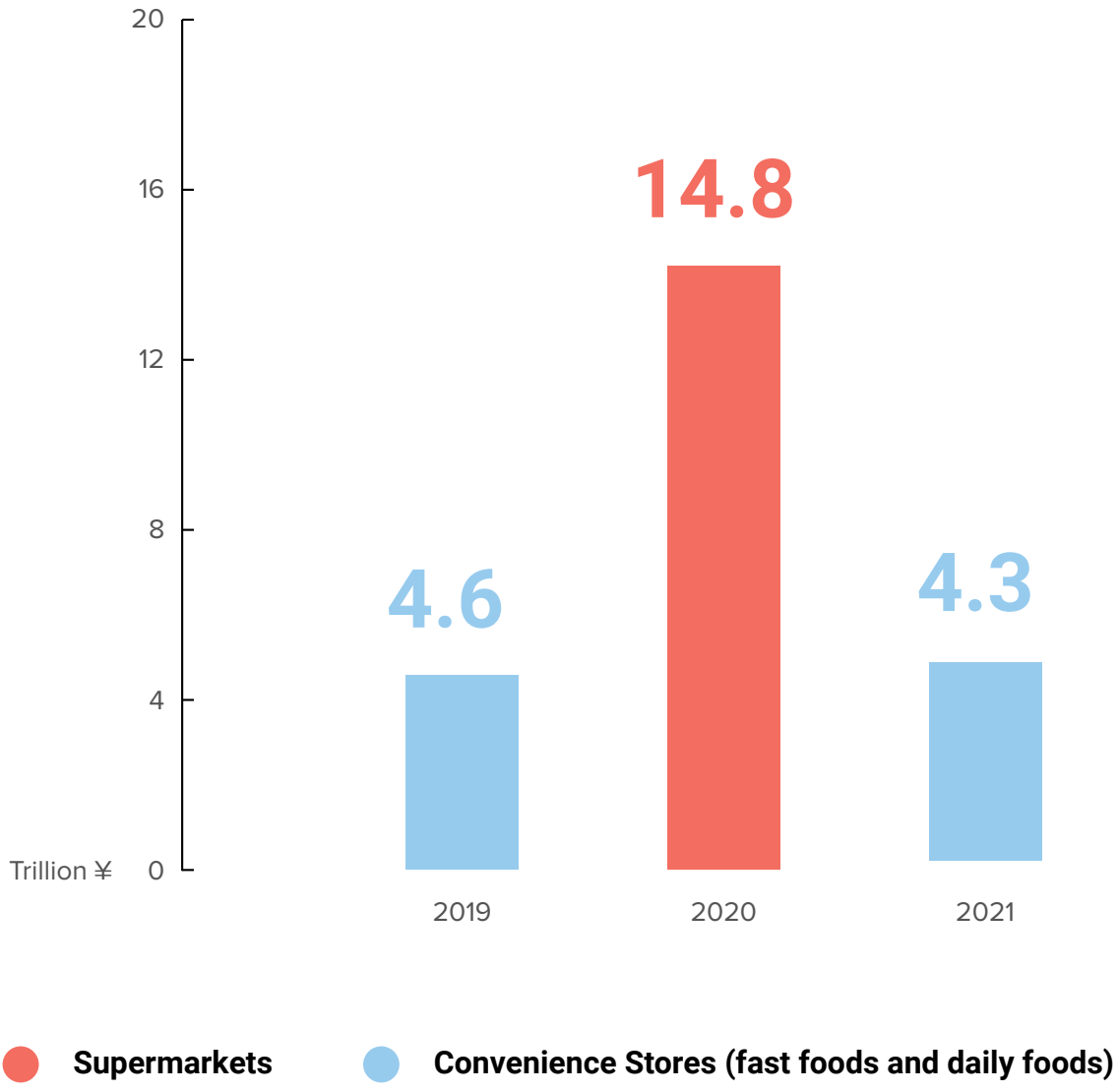
Since 2014, government subsidies have been a major driver of growth for natural refrigerant systems and has led to an increase in the number of CO_2 transcritical installations in Japan. The stated goal of the subsidy is to encourage the "shift to natural refrigerants … and to widely promote the use of energy-efficient equipment," states Japan's Ministry of the Environment (MOE). The subsidy aims to "contribute to driving down the cost of natural refrigerant equipment to achieve cost parity with conventional f-gas equipment, and to accelerate the spread of the technology."

The scheme targets the food retail and food manufacturing sector as well as cold-storage facilities. In the financial year 2018 (FY2018; April 1, 2018–March 31, 2019), the scheme operated with a budget of ¥6.4 billion (US$48 million). In FY2019 it increased to ¥7.4 billion (US$56 million), then to ¥7.3 billion (US$55 million) in FY2020, FY2021 and FY2022.[99]

In FY2021, 138 industrial refrigeration and 178 commercial refrigeration projects received subsidies for installing natural refrigerant systems. In 2015, the numbers were 76 and 557, respectively.

Industry observers expect the subsidies to continue over the next five years.

Japanese Food Retail Revenues



Source: Statista

3.4 High Pressure Gas Safety Act

Japan's High Pressure Gas Safety Act restricts the use of CO_2 in large refrigeration systems, subjecting manufacturers to heavy administrative burdens. However, in July 2017, the High Pressure Safety Institute of Japan (KHK) announced that CO_2 would be reclassified under the Act, moving from the strictest level of Group 3 to the least restricted level of Group 1.

This means that several administrative restrictions such as government notification or permission are no longer required for any manufacturer of CO_2 equipment with a daily refrigeration capacity under 20TR/70.3kW (previously under 3TR/10.6kW).

The regulatory change opened the door to significantly wider adoption of larger CO_2 systems in commercial and industrial applications in Japan. We expect to see more large transcritical CO_2 systems entering the Japanese market.

3.5 Standards for Hydrocarbon Cases

Following a lengthy risk assessment process spanning several years, Japan published Japanese Industrial Standard (JIS) C 9335-2-89:2021 in March 2021. The standard, which was developed based on the IEC 60335-2-89:2019 standard, specifies the increase in the maximum refrigerant charge for commercial refrigeration equipment as 13 times the Lower Flammability Limit (LFL). For R290, this amounts to 494g (17.4oz).

Subsequently, the Japan Refrigeration and Air Conditioning Industry Association (JRAIA) published a new standard (JRA 4078 2021) and new guidelines (JRA GL-21 2021), which are based on the new JIS standard and specify in more detail safety standards and requirements for equipment manufacturers adopting hydrocarbons.

The new JIS standard, in combination with the new JRAIA standards and guidelines, is expected to have a major positive impact on the uptake of hydrocarbon cases in Japan's commercial food retail sector, serving as a clear indication of the direction of the market over the next few years.

CHAPTER 4

General Trends Impacting the Growth of Natural Refrigerants

4.1 Sustainability and Net Zero

European retailers that invest in sustainable refrigeration systems are appealing to a large segment of their customer base. According to a July 2022 McKinsey & Company article, "Decarbonizing Grocery," 37% of European consumers deeply care about sustainability – a concern that cuts across all generations.[100]

Sustainability also matters in the competition for talent and investment capital. "Employers that are perceived as sustainable stand a better chance to attract, retain, and inspire purpose-driven people," says McKinsey. "Meanwhile, more and more investors are adopting environmental, social, and governance criteria and channeling capital to sustainable companies."

Emissions stemming from refrigeration come under scopes 1 (direct emissions of refrigerants) and 2 (indirect emissions from electricity usage, tied to efficiency of refrigeration). About 4% of a typical grocer's emissions fall under scopes 1 and 2, and many retailers have already set reduction targets for these emissions, according to McKinsey.

In some cases, grocers will be able to curb emissions simply by optimizing operations—for instance, by increasing the temperature in fridges. In another example, a British grocer installed technology to redirect cold air back into the fridges, resulting in a 15% reduction in energy use without having to install doors.

Many grocers are speeding up the pace at which they upgrade equipment, says McKinsey. For example, one Southern European grocer used to refurbish its stores every 10 years; now it has switched to a five-year cycle to reduce scope 1 and 2 emissions.

"Most of the top grocers in Europe have set net-zero targets for scopes 1 and 2, with one leading retailer committing some €1 billion to achieve net zero by 2040, while the most ambitious among them aspire to reach net zero as early as 2030," says McKinsey.

Among industrial sectors, the heating and cooling sector is the most advanced in net-zero pledges, says the International Energy Agency (IEA).

Meanwhile, Race to Zero, a UN-backed global campaign, is rallying non-state actors – including companies, cities, regions, financial and educational institutions – to take rigorous and immediate action to halve global emissions by 2030 and deliver a healthier, fairer zero-carbon world. The initiative mobilizes a coalition of leading net-zero initiatives, which in 2021 representing 31 regions, 733 cities, 3,067 companies, 624 educational institutions, 173 investors and over 3,000 hospitals. Another major carbon-reduction program is the Science Based Targets initiative (SBTi).

Race to Zero, among other groups, is supporting the Pathway to Net-Zero Cooling Initiative.[101] The initiative includes three elements: passive cooling; super-efficient equipment and appliances; and ultra-low GWP refrigerants and insulation foam gases.

There is already a small but growing number of supermarkets around the world aspiring to be net zero in energy production, in addition to using natural refrigerants that are near zero in GWP. While expensive to build, these stores have vastly lower energy costs and make important contributions to their countries' goal to become net zero overall.

In line with net zero, there are several food retailers and warehouses expanding implementation of rooftop solar panels at stores and warehouses and using thermal storage. Already Woolworths in Australia is committed to using 100% renewable energy by 2025.[102]

This aligns with more general trends. In 2020, renewable energy accounted for 23% of the total energy used for heating and cooling in the EU, steadily increasing from 12% in 2004 and 22% in 2019, according to Eurostat.[103] Among the EU member states, Sweden stands out with two-thirds of the energy used for heating and cooling in 2020 coming from renewable sources.

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The more ambitious the net-zero targets, the faster the transition to natural refrigerant technologies. We expect targets to become increasingly ambitious in the period leading up to 2030 as climate action comes to the forefront of many political and business agendas, not only in a race to net zero, but to avoid a climate crisis.

Clean energy goes hand in hand with the use of natural refrigerants in a company's sustainability portfolio. Companies that employ solar and the like – a growing number in the years ahead – will be also inclined to use natural refrigeration as well.

Moreover, in the "Pathway to Net-Zero Cooling" Report, the 2030 target is for all new cooling technologies across most applications to have ultra-low-GWP or no-GWP solutions, assuming barriers have been successfully addressed. This obviously supports the uptake of natural refrigerants.

4.2 Competition from HFOs

As the global shift from high-GWP refrigerants drives the search for low-GWP alternatives, the recent rise of hydrofluoroolefins (HFOs), the latest generation of fluorinated refrigerants, is undeniable. With their sub-10 GWPs, HFOs are considered the biggest competitor to natural refrigerants and are growing incredibly fast.

While pure HFOs like HFO-1234yf are widely used as a substitute for HFC-134a in mobile air-conditioning (MAC), combinations of HFOs and HFCs (blends) are more commonly employed in commercial and industrial refrigeration.

In the EU as a whole (plus the U.K.) in 2020, HFOs (unsaturated HFCs or HCFCs) represented 22% of the total amount of f-gases in metric tons, according to the European Environment Agency (EEA).[104]

However, in Europe, under the EU F-gas Regulation, as of January 1, 2022, refrigerants of 150 GHP or greater are banned in new refrigerator and freezer cabinets for commercial use that use hermetically sealed compressors. The same ban applies to new multipack centralized refrigeration systems for commercial use that have a cooling capacity greater than or equal to 40kW; if these are cascade systems, then the ban f-gases with a GWP of 1,500 or greater.

This means that only f-gas blends with a GWP of under 150, such as R454C and R455A, which have a GWP of 148, are allowed in these applications. Notably, those blends are rated A2L (slightly flammable). However, in January 2022, Honeywell announced a new A1 (non-flammable) refrigerant – R471A – for medium-temperature commercial refrigeration applications with a GWP of 148. It is a blend of HFO-1234ze (78.7%), HFO-1336mzz(E) (17%) and HFC-227ea (4.3%). Notably, HFC-227ea, a fire suppressant, converts 100% in the atmosphere to trifluoroacetic acid (TFA).[105]

According to industry observers, HFO blends are getting less usage in plug-in cases, which are heavily gravitating to R290 and R600a.

In any event, retailers in Europe and elsewhere that opt to retrofit only their refrigerant (typically an HFC) in an existing central system, rather than replace the entire system, are using HFO blends like R449A and R448A as "drop-in replacements." Natural refrigerants require an entirely new system and can't be used as drop-ins.

Whether or not these drop-in solutions represent a bridge to the eventual installation of a natural refrigerant system will depend on many factors, including regulations, equipment cost, total cost of ownership and most important, the long-term viability of HFOs. Indeed, reputable reports citing the growing health, safety, and environmental risks of HFOs have been surfacing for several years.

In a 259-page 2021 study of the environmental impact of HFOs, the German Environment Agency (UBA) concludes that HFOs used as refrigerants, foam blowing agents and aerosol propellants "should be replaced by more sustainable solutions with halogen-free substances" such as natural refrigerants.[106]

The UBA report focuses on the degradation products of HFOs, notably the rapid atmospheric conversion of HFO-1234yf into trifluoroacetic acid (TFA), which descends to earth in rainfall. Because of the persistence of TFA in the environment and the difficulty of removing it from groundwater and drinking water, the UBA says that the use of HFOs as substitutes for HFCs "must be regarded as problematic."

While not currently regulated, the TFA is collecting in the environment, according to a number of recent studies, which largely attribute this to expanding emissions of HFO-1234yf. The environmental group Greenpeace has called on governments to list HFOs in the Annex of Controlled Substances of the Kigali Amendment in order to track HFO production, consumption and the amount released to the atmosphere.

In sufficient quantities, TFA can be a destructive substance. In pure form, it is harmful when inhaled,

and causes severe skin burns. But even at extremely small concentrations in drinking water, TFA is potentially harmful to human health. Moreover, it is difficult to remove from the fresh water bodies that supply drinking water using conventional methods.

In Germany, UBA has set a human health "orientation value" limit of 60 µg/L for TFA in drinking water and a "precautionary measure" of 10 µg/L. The concentration levels of TFA in the environment have begun to approach – or exceed – those levels in some studies.[107]

Long-term exposure to TFA can potentially damage the liver and the thyroid function in humans, according to a report released in 2021 by Refolution Industriekälte, a German consulting and engineering firm focused on sustainable refrigeration.[105]

Some aquatic life may already be feeling the effect of TFA, according to a wide-ranging 2017 HFOs/TFA study by the Norwegian Environment Agency. Exposure of freshwater green alga to existing levels of TFA in Malawi, Chile and Germany was found to "equate to there being an environmental risk," the report said.[108]

Both TFA and HFO-1234yf fall under the definition of PFAS (per- and polyfluoroalkyl substances) established by the OECD (Organisation for Economic Co-operation and Development) and used by scientists around the world.107 PFAS encompass a well-known group of chemicals such as PFOA, PFOS and GenX, that have been linked to harmful health effects.

Adopting the OECD definition of PFAS, five European countries announced in 2021 their intention to submit a joint proposal to restrict some HFC and HFO refrigerants and TFA as PFAS under the EU's REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) regulation.23 The European Chemicals Agency (ECHA) is addressing the proposal in 2023.[109]

In the U.S., the Environmental Protection Agency (EPA) uses a different definition of PFAS that does not include f-gases or TFA; however, the agency's narrower definition has come under considerable criticism from U.S. scientists, and a bill has been put forward to change the EPA's definition to the OECD's.[107]

Meanwhile, a study by researchers at the University of New South Wales in Sydney, Australia, suggests that elevated levels of HFC-23 (R23) in the atmosphere could be linked to the commercial uptake of HFO-1234ze, which the study says produces R23 as a significant decomposition product. R23 has a super-high GWP of 18,400. If proven, this would impact the use of R471A.[107]

In line with the Australian study, the Environmental Coalition on Standards (ECOS), a Brussels, Belgium-based NGO, is calling for the European Commission (EC) to evaluate the "life cycle GWP" of HFO alternatives to HFC refrigerants, which considers the climate impact of their manufacturing processes and atmospheric degradation products, in addition to their direct global warming effect.[107]

Eventual regulation of HFOs?

With the backing of the major multinational chemical companies, HFOs and HFO blends will continue to be a formidable competitor for natural refrigerants and gain market share in the near term as HFCs are phased down. However, given the growing research into the potential risks and negative impacts of HFOs, it's reasonable to believe that policymakers will become increasingly concerned and eventually enact regulations of HFOs and HFO blends

If HFOs are restricted, this would leave natural refrigerants as the only viable alternative, creating a massive boost for the natural refrigerant industry.

As Europe is the world's leading regulator of refrigerants and home to many of the major studies on the impact of HFOs, we expect this to be where HFOs will be initially regulated, possibly beginning next year. The German government has been especially proactive in its research and vocal about its concerns.

4.3 Improving Efficiency

HVAC&R equipment contributes greenhouse gases to the atmosphere in two ways: directly, through leaked or vented refrigerants, and indirectly, through electricity usage, with the latter representing up to two-thirds of GHG emissions.[110]

One way to reduce electricity usage and cut energy costs – and help the environment if the energy is powered by fossil fuels – is through proper maintenance of HVAC&R equipment. A white paper by the Clean Cooling Collaborative (formerly the Kigali Cooling Efficiency Program) estimates that better optimization, monitoring and maintenance of cooling equipment globally has the potential to save 30Gt of CO_2 emissions by 2050.[111]

The efficiency of HVAC&R equipment can also be improved by investing in components designed to maximize performance like variable-speed drives, ECM fans and enhanced heat exchangers. For example, in 2021 Evapco, a major U.S. manufacturer of heat transfer products, introduced a new finned coil design, called the Ellipti-fin, which boosts thermal performance of closed-circuit coolers and evaporative condensers, improving efficiency by an average of 25%, the company said.[112]

The inclusion of a vapor quality sensor is the key to improving the efficiency of a low-charge ammonia DX (direct expansion) industrial system for low- and medium-temperature applications, according to Danish manufacturer HB Products.[113]

In addition, natural refrigerants, which already cut direct emissions due to their ultra-low GWPs, also typically boost the efficiency of a refrigeration or air-conditioning system.

Ammonia is widely recognized as a highly efficient refrigerant by itself and in concert with glycol or CO_2.[114] Hydrocarbons like R290 also improve efficiency, while CO_2 systems can operate with high efficiency in even warm climates when equipped with technology like adiabatic gas coolers, parallel compressors and ejectors.[115]

In 2021, Italian component manufacturer Carel published a white paper on how to achieve the most efficient natural refrigerant systems that can optimize energy savings and reduce indirect CO_2e emissions.[116]

In December 2021, 14 countries signed the Product Efficiency Call to Action, which aims to double the efficiency by 2030 of four priority products – air conditioners, refrigerators, industrial motor systems and lighting – that account for 40% of global energy consumption.[117]

Establishing the efficiency benefits of natural refrigerants is a key way to drive adoption of natural refrigerant equipment. Ample evidence already exists that all natural refrigerants can deliver these efficiencies. Moreover, the efficiencies offered by natural refrigerants can be optimized over time via proper equipment maintenance and investment in efficiency-enhancing components.

4.4 Digitalization

Digitalization of the commercial and industrial refrigeration industry has been moving forward at warp speed for the last few years, a trend that is expected to continue unabated, as the Internet of Things (IoT), automation and artificial intelligence (AI) open up new avenues for digital controls.[119]

Several factors – such as rising energy costs, ongoing technician shortages and aging compressor racks – are driving the adoption of a growing array of digitized control and sensor devices that monitor every aspect of HVAC&R systems.

The lockdowns caused by the COVID-19 pandemic in 2020 also highlighted the need for access to information when physical access to equipment isn't convenient or possible.[120] Data is needed to ensure that commercial refrigeration systems are staying cold enough, working efficiently, and keeping up with fluctuations in product demand, external temperatures, and other variables.

AI-based software can automatically detect outlier systems so that a technician can change faulty components, either remotely or in person.

In addition, the energy savings enabled by advanced monitoring systems will be critical to helping a company's bottom line, as well as an important element of reaching 2030 climate goals. Controls also help curb leaks of climate-polluting HFC refrigerants in a legacy system.

A third-party company specializing in digitalization of commercial refrigeration is Oakland, California-based Axiom Cloud. At a grocery store in Southern California, Axiom's "Virtual Technician," an artificial intelligence-based app, was able to catch the beginning of a liquid flooding event in the suction header of a medium-temperature rack – which could have severely damaged the compressors if allowed to progress.[121]

Synergy with natural refrigerants

Natural refrigerant systems like transcritical CO2 depend on robust control systems at the rack and case level to support efficient operation, particularly in warm climate zones. This is a key part of reducing their operating costs and achieving a good ROI. Moreover, forward-thinking retailers will see the synergy between modern control systems and natural refrigerant systems as part of a green refrigeration strategy.

4.5 Training of Technicians

Technical training is the backbone of the HVAC&R industry and what enables it to continue evolving and embracing new technologies. Indeed, it is the lack of technicians' training and qualifications that is cited by many industry players as a key deterrent to the adoption of natural refrigerant-based technology.

However, as other factors, like government policy changes, drive the uptake of natural refrigerant systems, greater attention had been given to training. Since 2021, many stakeholders around the world, from OEMs to schools and associations, have been stepping up their training offerings for natural refrigerants, taking away this obstacle to rapid deployment.[122]

Across the industry, many OEM providers of natural refrigerant equipment to supermarkets and industrial operators are confident that training opportunities are available, to the point where natural refrigerant training has become an expected commodity. At the same time, educational institutions are increasing training offerings that include certifications.

The COVID-19 pandemic cut into in-person training opportunities in 2020 and 2021, moving some to the internet. But the need for hands-on instruction has driven the resumption of in-person training in most instances.

At the same time, free online instruction, such as that offered by Danish OEM Advansor on commissioning and servicing of CO2 refrigeration systems, remain a vital component of natural refrigerant training.[123]

A good example of the growing support for natural refrigerant training occurred last year when the Center for Energy Technology (ZET) at the University of Bayreuth, Germany, provided a commercial-size air-conditioning system using CO2 as the refrigerant to the Kulmbach Vocational School Center (BSZ), in Kulmbach, Germany, for vocational training and research.[124]

Overcoming the barrier

While greater adoption of natural refrigeration systems is forcing the development of more training opportunities for technicians, the upsurge in training is also leading to more support for natural refrigeration. This is removing a key barrier to natural refrigerant adoption and giving confidence to end users considering these systems for the first time. At the same time, many regions still lack sufficient training and will need to address that issue to ensure the transition to natural refrigerants.

4.6 Growth of Frozen and Fresh Foods

Even prior to the COVID-19 pandemic, sales of frozen foods had been on the rise. According to the 2019 "Power of Frozen" report by the American Frozen Food Institute (AFFI) and the food industry association FMI, 2018 sales of frozen foods in the U.S. topped US$57 billion (€57.5 billion), up 2.6%.[125]

The AFFI/FMI report said that shoppers in urban and suburban areas – the fastest growing population centers – consume frozen food more often than other groups. And according to CB Insights, millennials spend 9% more on frozen foods per supermarket visit than households of other age-based demographics.[126]

In addition to the growth in frozen foods, U.S. retailers of all types are seeing upticks in refrigerated fresh foods, including everything from pre-made food offerings to meal kits. In 2017, L.E.K. Consulting projected that U.S. consumer spending on fresh prepared food would grow from US$34 billion (€29 billion) in 2016 to US$51 billion (€43 billion) in 2021.[127] This trend follows what has already been established in countries like the U.K., where consumers can grab premium wraps, ready-to-eat ethnic meals, salads and many other offerings.

The COVID-19 pandemic accelerated these trends, especially in March–April of 2020. According to the AFFI, during that period 7% of consumers who purchased frozen foods said they had not purchased frozen food items pre-pandemic or had done so very infrequently.

This could have a lasting impact on purchase habits. Indeed, in January 2022, frozen food sales in the U.S. were up 26% compared to January 2020, according to an article in Quartz.[128] This is partly because of inflation, as consumers switch to less expensive frozen offerings.

The upsurge in frozen food sales has led to more equipment purchases, both by consumers and retailers, according to Anne-Marie Roerink, president of 210 Analytics, a market research company focused on the food industry, quoted by Quartz. Thirty percent of U.S. shoppers increased their freezer capacity during the pandemic, and a similar trend is taking place in the U.K. Meanwhile some supermarkets are adding an extra aisle with freezers and putting freezers in different parts of the store.

Opportunity for NatRefs

The rise in frozen and fresh food sales will translate into a greater need for refrigeration, particularly additional display cases in existing stores. This unlocks an opportunity for self-contained R290 plug-in cases and CO_2 condensing units.

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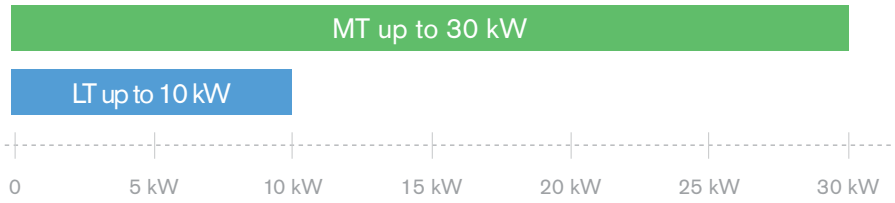

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4.7 The Online Grocery Boom

Online grocery, which has taken on new significance in the age of COVID, continued to grow in revenues across Europe in 2021, rising by 8.8% compared with 2020 levels, according to McKinsey & Company.[3] In North America, online grocery sales have grown nearly 60% since the beginning of the pandemic, though penetration rate has leveled off.[36]

According to FMI, little more than a third of U.S. consumers shop only in stores, half occasionally shop online, while the rest (16%) rely mostly on online purchases.

McKinsey's research suggested online growth might "take a year-long pause" in 2022 in many markets. This pattern could be especially evident in markets that have less-developed online offerings, where consumers might even reduce their spending online.

But going forward, McKinsey expects online growth to continue, with e-grocery reaching above 20% of total share in 2030, depending on the country and scenario.

To create growth, online offers need to become more "differentiated" and tailored to the needs of additional consumer groups and shopping missions, says McKinsey.

The most prominent new online market segment is "instant delivery" – typically within 30 minutes, often delivered by drivers on electric bikes or scooters. It offers the fastest and most convenient delivery of a reduced assortment at a higher price per item, similarly to what convenience formats offer in the offline channel.

Online players differentiate themselves through larger assortments (for example, Ocado), local or organic offerings (for example, Farmy in Switzerland and Rohlik), or a lean value proposition (for example, Picnic).

Thanks to these more differentiated online offerings, McKinsey sees consumers starting to split their online purchases across different online shops. About one-third of frequent online shoppers (that is, those who shop online at least once a week) regularly order from three or more e-grocers. The more often consumers shop online, the more online grocers they use. There is therefore a good chance that as the online market matures, several different online formats and value propositions will coexist and compete for consumer baskets.

Within online, instant delivery experienced a year of marked expansion in 2021 with major inflows of funding, says McKinsey. In the first nine months of 2021, nearly $5.8 billion (€5.9 billion) was invested globally in "dark convenience stores" or microful-fillment centers.

Still, the instant market remains small. McKinsey research suggests that the instant-delivery market in Europe reached between €3 billion and €6 billion (US$3.1 billion and US$6.1 billion) in 2021, accounting for less than 1% of the total market but with three-digit percent growth annually.

Incumbent grocers, notes McKinsey, have responded with instant propositions (for example, Ocado Zoom, Sainsbury's Chop Chop), partnerships, or even "VC-like" investments in instant players (for example, Carrefour and Cajoo, and Rewe and Flink). In the U.S., Instacart and Shipt are expanding their engagements with grocers, while DoorDash has partnerships with Smart & Final, Meijer, Fresh Thyme, and Albertsons, among others.

While in most cases online shopping means having orders delivered to shoppers' homes, another option is "click and collect," whereby shoppers pick up their online orders at a store or other location from a refrigerated locker.

Click and collect has experienced considerable development since 2018, becoming a tool of large-scale retailers, particularly in Europe. For example, in early 2020 it accounted for 7% of total grocery sales in France, according to Epta, which produces the #EPTABricks click-and-collect R290-based refrigerated lockers.[129] Because of the COVID pandemic, Epta saw a 300% jump in sales of #EPTABricks in April 2020 (compared to the same

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period in 2019). In 2022, in Italy, 34% of online shops offered the click & collect option, said Epta.

Click-and-collect solutions offer shoppers a convenient shopping experience, minimizing waiting times and being available 24/7. It allows a significant increase in online order collection points and makes it possible to collect the order on the same day.

#EPTABricks, for example, can be installed close to metro stops, companies, hospitals, schools and offices – not necessarily close to the store of origin. Retailers can thus increase their presence in areas where it is not possible to open physical stores.

Retrofit opportunities

Internet shopping is having a strong impact on the format of stores and consequently on the type of equipment. This is resulting in new opportunities for retrofits and installation of refrigeration equipment with R290 or CO2 – potentially even low-charge ammonia for microfulfillment centers. Dark stores are used by employees, but not by customers, allowing more space for items. This could raise the demand for refrigeration, since there will be more space for refrigerated cases.[120]

In Europe, click and collect, using R290 refrigerated lockers, is expected to experience healthy growth over the next few years. Epta projects click and collect will reach a turnover of around €45.1 billion (US$44.6 billion) in Europe in 2023.

4.8 Cooling-as-a-Service

Largely thanks to the focused efforts of the Cooling as a Service (CaaS) Initiative, driven by the Swiss- based Basel Agency for Sustainable Energy (BASE), servitization within the cooling sector is becoming an increasingly popular choice to finance natural refrigerant projects without the barrier of upfront investment.

Under CaaS, end users pay for the cooling service instead of investing in the infrastructure that delivers the cooling. The technology provider owns the cooling system, maintains it, and covers all operational costs including electricity.

The periodic payments made by the end-user customer are fixed-cost-per-unit and based on metered usage; thus, the customer does not bear any risk related to the performance of the cooling equipment. Meanwhile, the technology provider has the incentive to install equipment offering the lowest life cycle cost to make the service more cost-effective.[130]

CaaS passed the US$50 million (€41.62 million) global investment milestone in late 2020 and is gaining momentum fast as the model is mainstreamed in the HVAC&R sector globally.[131] With success stories in a myriad of applications and regions, the model has already enabled natural refrigerant systems in countries such as Nigeria and South Africa.

Business models like CaaS can support the "urgent need" for transition to energy-efficient cooling systems that use cleaner, "ideally natural" refrigerants, according to a recent white paper published by BASE.[132]

In the report, BASE emphasizes how the long-term mindset created by the CaaS business model promotes sustainable choices within the sector, including the selection of refrigerants.

In March 2020, Sphere Solutions, a major South African manufacturer of transcritical CO_2 systems, and its partners met with the five commercial banks in South Africa to discuss cooling-as-a-service as the means for implementing transcritical CO_2 refrigeration systems in South Africa.[133]

Removing multiple barriers

Alternative financing solutions such as CaaS eliminates multiple known barriers to the uptake of natural refrigerant solutions, including higher CAPEX and lack of technician skills. It removes this burden from the end user, who now only pays for the cooling used and no longer maintains the system. This makes switching to natural refrigerants a much less daunting exercise for an end user, taking away a significant portion of perceived risk.

As the model gains popularity and more successful case studies emerge from all around the world, CaaS has the potential to drive the widespread uptake of natural refrigerants – in both the developing and developed world.

4.9 Clean Cooling: A New Standard for Sustainable Cooling

A new paradigm is taking root in the HVAC&R industry that reflects the demand for refrigeration and air-conditioning equipment that is not only climate-friendly but also meets the cooling needs of all people. This paradigm is called Clean Cooling, developed by Toby Peters, Professor in Cold Economy at the University of Birmingham, U.K., in coordination with ATMOsphere.[134]

The concept of Clean Cooling will ultimately be employed as a set of measurable standards against which cooling innovation and projects can be assessed. These standards will help all stakeholders to properly understand and quantify the true sustainability (financial, social and environmental) of cooling technology, including CO_2e emissions reduction. A definition of Clean Cooling that explains all of these elements was published in 2020.[135]

At a minimum, Clean Cooling systems require the lowest-possible GWP refrigerants, preferably natural refrigerants, as well as the highest possible efficiency. Other basic elements include demand reduction, repurposing of waste heat, doors on chilled display cases in supermarkets, regular preventive and predictive maintenance to ensure optimal operating performance, and proper end-of-life disposal.

Clean Cooling is needed to fill the gaps in developing countries. Thus, Clean Cooling initiatives have been focused on big markets like India and China, as well as markets such as Sub-Saharan Africa and regions like the GCC (Gulf Cooperation Council), which includes Saudi Arabia, Kuwait, the United Arab Emirates, Qatar, Bahrain and Oman. However, Clean Cooling is meant to be a global paradigm that applies to developed countries no less than developing ones.[136]

Profound implications for NatRefs

Clean Cooling is an emerging concept that is in the early stages of implementation. But its effect on the marketplace could be profound, including a broader adoption of natural refrigerants.

4.10 The Growth of Smaller Stores

One of the major shifts taking place in food retail is the proliferation of small-format stores, particularly in urban areas. In Japan, this is already common practice.

While R290 plug-in cases are increasingly used throughout small stores, CO_2 condensing units (as opposed to racks) are another option gaining momentum.[137] There are already multiple rack manufacturers supplying CO_2 condensing units to these small-format stores.

OEMs boast thousands of successful installations – especially in Europe – and there is a growing number of natural refrigerant solutions entering the market targeting smaller cooling capacities as well.

Small stores already make up a large percentage of food retail outlets in Europe, according to a November 2020 RefNat4LIFE report on sustainable cooling in the European organic and small food retail sector.[138]

In 2015, the report estimated that 85% of European supermarkets had a maximum sales area of less than 1,000 m^2 (10,764ft^2). The share of the small food retail market varies within European countries. In 2015, the Netherlands had the lowest share with 67%, followed by France and Germany in the range of 75%. In contrast, Poland stood out with by far largest share with 99%, followed by Austria, the Czech Republic and Italy, which all exceeded 90%.

For the smallest food stores, with less than 400 m^2 (4,306ft^2) sales area, the most popular refrigeration systems are plug-in, stand-alone systems, whereas stores between 400 and 1,000 m^2 sales area are more prone to using centralized refrigeration systems.

In organic food retail (OFR), the average cooling capacity of centralized systems is around 25kW (7.1TR) for stores with a sales area of 400 to 999m^2; for stores below 400 m^2, the capacity is 6 to 7kW (1.7 to 2TR).

However, most small food retailers have limited knowledge about the key technical specifications of their refrigeration systems, such as the refrigerants used, their energy consumption and running costs. They therefore lack an understanding of its cost and environmental impact.

Thus, these stores should be targeted for an educational campaign on natural refrigerants.

CO_2 vs. hydrocarbons

In Europe, in 2020, 3.9% of the transcritical CO_2 sites in Europe were using condensing units, according to ATMOsphere research. This percentage grew to 9% in 2022 and is expected to increase gradually in the coming years as OEMs continue installing them in small-format stores, gas stations, fast-food chains and restaurants.

In North America, there is interest in CO_2 condensing units but a lack of availability of the technology; however, that is changing, as Hillphoenix introduced a CO_2 condensing unit for stores last year[198] Hillphoenix has also installed its first CO_2 system in a convenience store, a small-store format that represents an opportunity for natural refrigerants in North America.[197]

But self-contained hydrocarbon cases will also garner a substantial share of the small-store market.

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CHAPTER 5

CO_2 Trends

5.1 The Impact of Market Leaders

In all markets, there have always been a few end users who like to investigate new technologies before their competitors. This has certainly been true for natural refrigerant systems, especially trans-critical CO_2 systems in the commercial refrigeration and industrial spaces.

These end users not only kick off a trend; they drive it over time and can be expected to continue installing new systems and retrofitting existing ones into the future. They also provide legitimacy to the technology, encouraging their competitors and others to eventually follow suit, thereby expanding the market.

In Europe, a number of retailers have launched aggressive transcritical CO_2 installation programs. These include German wholesale chain METRO AG, which had 133 transcritical CO_2 installations (including 37 with ejectors) as of September 2022, as well as Biedronka, Migros, Albert Heijn, and Sainsbury's.

In one of the most ambitious retrofit initiatives of its kind, Danish retailer Salling Group plans to replace old refrigeration systems in 725 stores with CO_2 racks as part of a DKK 2.5 billion (US$366 million) investment in energy efficiency technologies.[139]

The Sailing Group refrigeration refurbishment project includes stores in Denmark, Germany and Poland and is expected to conclude in 2026. In Poland 328 stores will be refurbished, 270 stores in Germany and 127 stores in Denmark. The retailer will also install glass doors on all cooling cabinets and freezers.

Salling Group operates the Netto and Føtex supermarket chains, the Bilka hypermarket chain and a smaller number of Salling department stores. Founded in 1906, the group has more than 1,700 stores.

In other regions, there are far fewer clear leaders, but they have had an outsized impact on the market. In the U.S., one to emerge is ALDI US, which had installed transcritical CO_2 in nearly 500 of its more than 2,000 stores as of May 2022.[195] In Japan the clear CO_2 leader is convenience store giant Lawson, which had installed CO_2 condensing units in 5,028 stores as of December 2022.

Influencing others

Market leaders should be expected to continue driving adoption of transcritical CO_2 in all regions. Sailing Group, ALDI US and Lawson will continue to have a significant impact on overall transcritical CO_2 adoption in their markets, both with their own installations and their influence on other end users

5.2 Improving CO_2 Efficiency in Warm Climates

Concerns around the efficiency of CO_2 refrigeration systems in warm climates have long been seen as a barrier to CO_2 uptake worldwide, with a so-called "CO_2 equator" dividing viable installations to the north from non-viable ones to the south. However, technology developments such as adiabatic condensing, ejectors and parallel compression have increasingly made CO_2 technology viable in all climates, including regions previously deemed not suitable.

Ejectors and parallel compression make CO_2 systems more efficient while operating in transcritical mode. Parallel compression compresses the excess gas at the highest possible pressure level. This leads to a significant increase of coefficient of performance (COP) in warm climates.[140]

Evaporative condensation, mechanical sub-cooling and adiabatic gas cooling decrease the outlet temperature of the gas cooler and force the system to operate longer in subcritical mode, thereby making it more efficient.

Manufacturers are continuing to come up with new ways to improve the efficiency of refrigeration systems, and there are multiple solutions from different companies already available on the market today.

For example, In a supermarket in Italy, 15–20°C (59 –68°F) groundwater is used as a cooling fluid to condense the CO_2 instead of air, allowing the system to run in subcritical mode even during the hottest summer months when the ambient air temperature is 28°C (82.4°F) or more.[141]

In 2021 Belgian retailer Delhaize, part of the Ahold Delhaize group, reported installing an evaporative cooling system on existing air-cooled gas coolers serving transcritical CO_2 systems at more than 100 corporate stores, effectively turning the gas coolers into energy-saving adiabatic systems.[142]

Delhaize's evaporative cooling system, called the chillBooster, from Italian component manufacturer Carel, consists of a cabinet with a pressurizing pump (10bar/145psi) and a system of nozzles mounted onto steel manifolds around the condensing unit.[143]

Delhaize installed the chillBooster retrofits in response to a series of heat waves during the summer of 2019, which caused refrigeration performance issues at some Delhaize stores.

Another new technology designed to improve the efficiency of transcritical CO_2 systems is the PXG1300, a pressure exchanger device made by Energy Recovery, a San Leandro, California-based manufacturer of pressure-exchanger devices for several industries.

A new store in Europe is the second retail location in the world to install a transcritical CO_2 system that uses the integrated pressure-exchanger device. The device is also being employed by Vallarta Supermarkets, a California chain with more than 50 locations, as a retrofit of an existing CO_2 system in a store located in Indio, California.[144]

Italian OEM Epta has designed its own technologies to improve the efficiency of transcritical CO_2 systems in warm climates, the FTE (Full Transcritical Efficiency) and ETE (Extreme Temperature Efficiency).[145] ETE goes an extra step, enabling efficient operation in temperatures higher than 40°C (104°F), said Epta.

The FTE system, Introduced in Europe in 2017 (with version 2 released in 2020), employs a low-pressure liquid receiver to flood medium-temperature evaporators with liquid CO_2. This eliminates superheat and allows the evaporation temperature in the cabinets – and ultimately the efficiency of the system – to increase.

Introduced in Europe in 2020, ETE uses a heat exchanger to subcool a portion of the CO_2 coming out of the gas cooler and delivers the refrigerant – expanded to an intermediate pressure level by the EEV (electronic expansion valve) – to the high-pressure line.

CO_2 anywhere

By removing the barrier that prevents CO_2 systems from operating efficiently in higher ambient climates, these technologies make it possible to install CO_2 systems in stores and warehouses anywhere in the world. This is leading to growth in CO_2 systems in regions previously not considered suitable – such as the southern U.S. – and this positive trend in CO_2 system growth is expected to continue.

5.3 The Growth of Integrated CO_2 Systems

There are at least two regions, Australia and Europe, that are seeing significant interest in integrated transcritical CO_2 systems, which combine refrigeration, air-conditioning and space/water heating (through heat reclaim).

In Australia, the large food retailer Woolworths has installed a number of integrated transcritical systems among its CO_2 installations and plans to use this technology where feasible.[146] A remodeled Michael's SUPA IGA store in Keysborough, Victoria, Australia, has also installed a fully integrated and highly efficient transcritical CO_2 HVAC&R system.[147]

In Europe, all of the 22 Delhaize Belgium supermarkets equipped with transcritical CO_2 systems in 2021 – 17 existing stores and five new – were scheduled to be integrated systems combining refrigeration, air-conditioning and heating.[148]

In 2022, Swiss cold storage operator Grünenfelder installed its first integrated CO_2 heating and cooling system for a facility in Quartino, replacing an old problematic R507A system with a TotalGreEnergy system from Swiss OEM Biaggini Frigoriferi.[149]

The new integrated CO_2 system from Biaggini, whose headquarters is located very close to Quartino, services five medium-temperature cold rooms, a 1,000m2 (10,764ft2) low-temperature room at -28°C (-18.4°F) and an unloading ramp. The system will also supply the air-conditioning system and heating. For the heat pump operation, the auxiliary system is using groundwater as the heat source.

In Switzerland it is mandatory to use natural refrigerants in systems above 20kW (5.7TR) capacity.

A number of European OEMs offer integrated transcritical CO_2 systems. Also in Europe, the MultiPACK project, an EU-sponsored initiative, supported the development of integrated transcritical CO2 systems, particularly in warm climates.[150] Launched in 2016, the project was completed in September 2021.

Coming to North America and Japan?

Integrated transcritical CO_2 systems are expected to be implemented widely in Europe, somewhat in Australia, and eventually in North America and Japan. The biggest driver is the energy savings and emissions reduction that comes from leveraging heat reclaim from refrigeration to heat a facility or generate hot water, thereby eliminating fossil-fuel heaters. In addition, by incorporating air-conditioning, the integrated system can reduce overall equipment costs. A caveat is that if an integrated system goes down, all applications would be affected.

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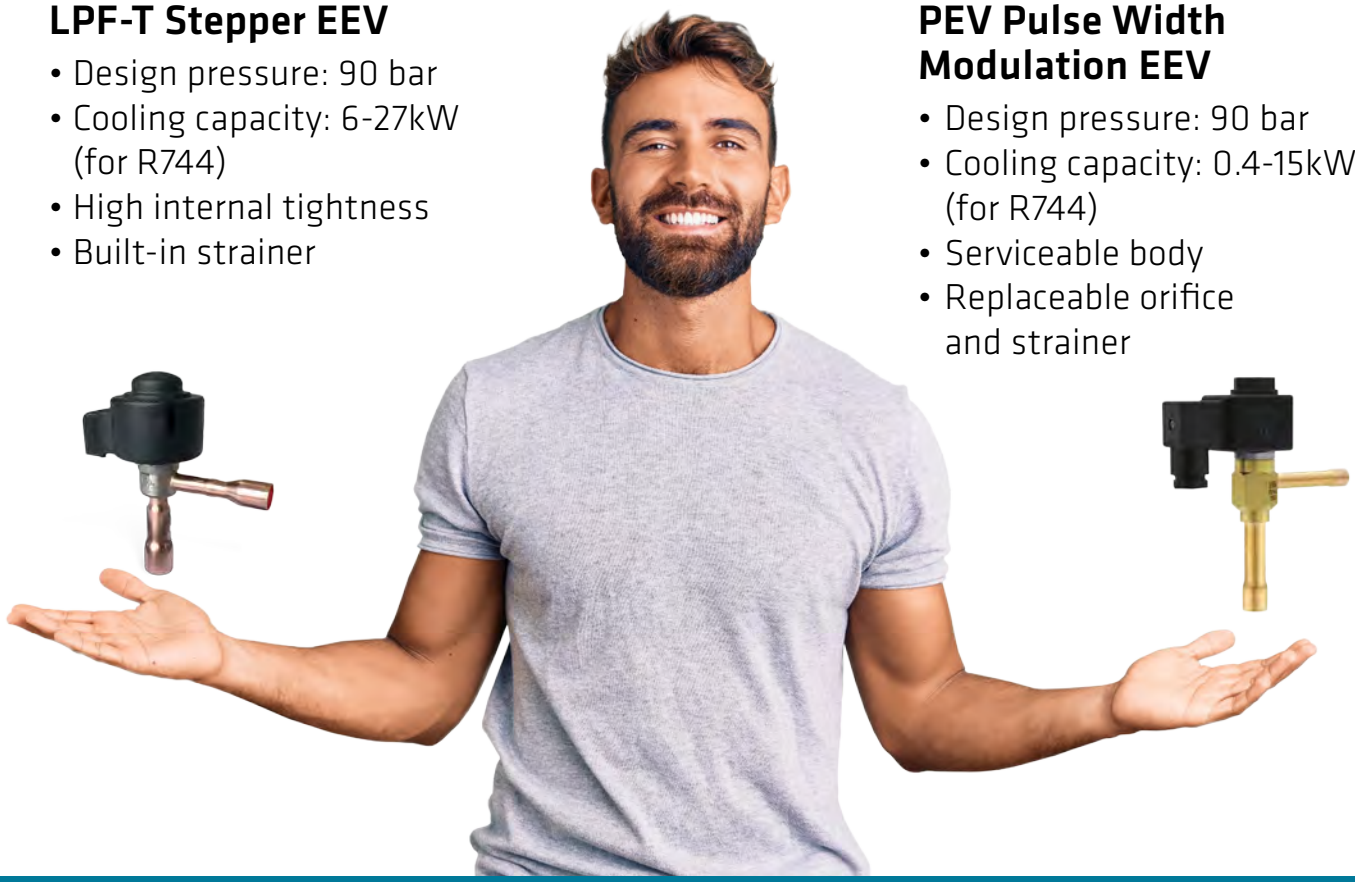

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5.4 Marked Growth of Transcritical CO_2 in Industrial Refrigeration

While transcritical CO_2 refrigeration was first used in supermarkets, it has gradually become a major option in the industrial space in cold storage, food processing and other applications, competing with ammonia and other refrigerants in all major markets.

In fact, CO_2 has emerged as a particularly strong refrigerant for low-temperature applications in cold storage and food processing. It is seen as a way of avoiding the safety protocols associated with ammonia refrigeration while still using a natural refrigerant. On the other hand, it represents a new technology for an industry that has long been accustomed to using ammonia.

Transcritical CO_2 systems were originally regarded as most suited to small- and medium-capacity industrial applications, but in the past few years transcritical CO_2 installations have been specified for larger installations as well, with cooling capacities of up to 4 MW (1,137 TR) being achieved.[151] This was helped along by CO_2 specific components, such as semi-hermetic reciprocating compressors in particular, being scaled to industrial sizes by manufacturers.[152]

Evidence of the growth of transcritical CO_2 in the industrial sphere comes from a survey of manufacturers, contractors, consultants/engineers and others working with the technology about their primary market sectors.[153] The data revealed that while the majority of these respondents are active in the commercial HVAC&R supermarket sector (41%), a further 30% are active in the industrial HVAC&R sector, including cold storage, food processing, pharmaceutical industry, chemical industry, etc.

Another sign of CO_2's relevance to the industrial sector is the publication in August 2021 of the International Institute of Ammonia Refrigeration's (IIAR's) ANSI-approved Safety Standard for Closed-Circuit Carbon Dioxide Refrigeration Systems.[154] IIAR has traditionally produced safety standards for industrial ammonia applications, but the trade group has recognized the growing use of transcritical CO_2 by industrial end users, and the need for standards to address CO_2.

In 2022, manufacturers on both sides of the Atlantic noted the significant progress of CO_2 in industrial applications.

For example, Maurice Robinson, Technical Support Team Leader for German OEM TEKO, said at the ATMO World Summit on March 31, 2022, that TEKO's inquiries for industrial CO_2 systems above 250kW (71.1TR) went from seven inquiries in 2017 to 185 in 2021.[155] For industrial applications above 500kW (142.2TR), the company went from a single inquiry in 2017 to 38 in 2021.

Robinson pointed out that several compressor manufacturers have invested in research and development to produce larger-capacity CO_2 compressors, and this has been a major driver of CO_2's increasing use in industrial refrigeration. Instead of 10 or 15 compressors in an industrial CO2 rack, six are possible.

U.S. component manufacturer Colmac Coil has seen a move away from both ammonia and synthetics towards CO_2 in evaporators for industrial applications, with CO_2's share of the company's output increasing from 5% in 2019 to 30% in 2022, said Jeremy Olberding, its VP of Sales, at the IIAR conference in March of last year.[156]

One of the reasons for the move towards CO2 is that it allows the removal of ammonia from the occupied space. Quoting what customers have told him,

OIberding said, “I love ammonia as a refrigerant; it’s efficient, but keep it away from my people, my processes and my products.” One way of doing that is putting CO_2 in the refrigerated space and keeping ammonia on the outside, as in cascade systems, he explained.

Sales of an industrial-size coalescent oil separator from U.S. component manufacturer Temprite are benefitting from the emergence of transcritical CO_2 as a force in industrial refrigerator, said Temprite President Jim Nonnie at the 2022 IIAR conference.[157] “For decades it’s been ammonia uncontested,” Nonnie said. “Now all of a sudden, here comes transcritical CO_2 taking a piece of ammonia refrigeration’s turf.”

Competing against other NatRefs

Robust growth is expected for transcritical CO_2 in cold storage and other industrial applications, especially for low-temperature applications. Its chief competitor will be ammonia, in particular low-charge ammonia and ammonia/CO_2 systems, given ammonia’s entrenched dominant position in industrial refrigeration, as well as propane in chillers. It will also compete – but to a lesser degree than in the commercial space – with HFO blends.

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5.5 European Retailers Report Energy Savings in Life-C4R/Epta Transcritical CO_2 Rack Project

Food retailers who participated in the Life-C4R (Carbon 4 Retail Refrigeration) project reported energy savings and other benefits associated with installations of transcritical CO_2 (R744) equipment in warm ambient climates during a webinar in 2021.

The webinar – hosted by Italian OEM Epta, which coordinated Life-C4R project – marked the conclusion of the three-year initiative.

Life-C4R, co-funded by the EU, was created to accelerate the implementation of very-high-efficiency CO_2 refrigeration systems as a way of reducing GHG emissions and cutting energy.

In the webinar, representatives of three European retailers – Conad Centro Nord, Consum and Mega Image – discussed the installations of Epta's transcritical CO_2 equipment, notably systems using the FTE (Full Transcritical Efficiency) 2.0 and/or ETE (Extreme Temperature Efficiency) technologies.

Also, at the webinar, Epta announced the availability of a new version of its ECO_2Large transcritical CO_2 rack that includes integration of the FTE 2.0 and ETE technologies.

"The two technologies at the heart of the Life-C4R project are FTE and ETE," said David Wirth, Product Manager for Epta during the webinar. The technologies have already been used individually and together over the past three years in "hundreds of installations," he added.

Saving 60,000 washing machine cycles

The first pilot project for the Life-C4R project, launched in October 2019, took place at a store operated by Conad Centro Nord in Carpenedolo, Italy, where summer temperatures frequently reach 35°C (95°F). The store installed Epta's ECO_2Small rack, including FTE 2.0, which saved 54,514kWh/year compared to standard solutions, according to Epta; that's equivalent to about 60,000 washing machine cycles.

"We appreciate the energy savings; it's really impressive," said Stefano Elli, Planning and Controlling Director for Conad Centro Nord. "With CO_2 and FTE, we feel we have found the efficient solution we were looking for."

Conad Centro Nord also installed an Epta system with ETE technology, as part of the Life-C4R project, at a store in Bologna, Italy, where it saved 55,868 kWh/year, said Epta.

The second Life-C4R Epta project took place at a new 1,400m2 (15,069ft2) Consum store in Benicasim, Spain – another high-ambient-temperature location – starting in January 2020. The store is using an Epta transcritical CO_2 system that incorporates both FTE 2.0 and ETE technologies. In 2020, Consum installed transcritical CO_2 systems in 17 new supermarkets, reaching 113 stores with CO_2 refrigeration out of a total of more than 700 outlets.

"Compared to an installation without FTE or ETE, there was a reduction of 15% [in energy consumption] measured last summer" at the Benicasim store, said

Javier Martínez, Organization and Control Executive for Consum, during the webinar. Over a year, the energy savings were 21,548kWh, Epta said.

The store's CO_2 system experienced "a considerable reduction" in compressor discharge temperatures, and an increase in evaporation temperature at medium-temperature cabinets, said Martínez. In addition, the system reduced condensation temperature, "practically eliminating the flash gas that causes inefficiency in high temperatures," he noted.

Overall, the Benicasim store showed that, "with currently available technology, CO_2 is efficient in hot climates such as ours," Martínez said. "We will maintain our commitment to CO_2 in systems that incorporate optimization solutions such as FTE 2.0 and ETE because of the ease of maintenance and the continuous energy savings 365 days per year."

Another Life-C4R pilot project was carried out at a Mega Image chain store in Sibiu, Romania, beginning in April 2021. The store installed an Epta ECO2Small pack with an FTE 2.0 system.

The installation is designed to reduce consumption by 10%, compared to an equivalent system with HFC, said Epta. That would save 38,573kWh/year, which is equal to 41,787 fewer washing machine cycles in a year or 1,052 fewer small cars in 10 years.

"The system has been very reliable and functions in tough conditions," including high ambient temperatures, said Vasile Casian, Technical Manager for Mega Image, a division of Ahold Delhaize, who also participated in the webinar. Mega Image plans to install more such systems, he added.

In addition to the two Conad Centro Nord stores, the Consum store and the Mega Image store, the Life-C4R project has conducted FTE 2.0/ETE pilots at supermarkets in Perugia, Italy (operated by Oasi);- Timisoara, Romania (Auchan); and Madrid, Spain (ALDI).

5.6 Irish Supermarket Transitions to NatRefs with Country's First Panasonic CO_2 Condensing Units

Independent Irish supermarket Nolan's, located in Clontarf, Dublin, was the first retailer in the country to install CO_2 (R744) condensing units from Japanese manufacturer Panasonic when it updated its entire refrigeration system to CO_2 in 2018.

A total of four Panasonic CO_2 condensing units were installed at Nolan's by Dublin-based contractor Tech RAC. One 10HP low-temperature condensing unit serves three cold rooms and a freezer, delivering 8kW (2.3TR) of cooling capacity at an evaporation temperature of -35°C (-31°F), and three 4HP medium-temperature (MT) condensing units, each delivering 7.5kW (2.1TR) of cooling capacity at an evaporation temperature of -10°C (14°F), serve "several satellite fridges," explained the installer.

"The CO_2 [condensing] units have a notable track record for reliability and efficiency with a clever two-stage compression rotary compressor and for it to be the first of its kind in Ireland is an impressive achievement," said Vincent Mahony, National Manager at Panasonic Heating and Cooling Ireland.

The supermarket's upgrade also included a centralized system, built by British manufacturer Clade UK, that comprises two CO_2 racks and serves 43 cabinets and display cases around the store. The rack system provides 80kW (22.7TR) of heating for the store by reclaiming waste heat, as well as air-conditioning if needed.

According to Tech RAC, Nolan's cold rooms, cabinets, counters and display units were all produced by German manufacturer Viessmann.

Transitioning to CO_2

The new CO_2-based refrigeration system was a significant part of a multimillion-euro modernization project at the supermarket to celebrate the 60th anniversary of the one-store family-run business. The refurbishment also included a 20,000ft^2 (1,858m^2) extension of the store's commercial space, effectively doubling its existing footprint.

Having previously used a CFC-based system, Nolan's wanted to transition to a reliable, efficient and environmentally friendly alternative for a long time, said Gavin Nolan, who is part of the family that owns and operates the store.

In addition to having a GWP of one and an ozone depleting potential (ODP) of zero, CO_2 as a refrigerant is also known for its high energy efficiency, which was a big appeal when choosing Nolan's refrigeration system, he explained.

"While the upfront costs were significantly higher than alternative options, we knew that those costs would be recovered during operation," he added.

According to Tech RAC, with the reclaimed heat for generating hot water and space heating, the efficiency of the system is improved even further.

Improving air quality

As a part of the project, Tech RAC also installed Panasonic NX cassette air-conditioning units fitted with its nanoe X technology, said Panasonic. The units are tied to the CO_2 rack system.

The unit includes a "powerful fan and intelligent sensors to ensure high energy efficiency and exceptional comfort with a circulation function to evenly distribute the air and minimize temperature gaps throughout the store," said the manufacturer.

"We are delighted to have been able to provide our CO_2 [condensing] units plus the NX cassette units with nanoe X technology, which helps to inhibit the effects of certain viruses and bacteria, both in the air and on surfaces for improved protection, 24/7," said Mahony.

5.7 French Seafood Processor Saves Up to 36% in Energy With CO_2 Cooling/ Heating

French seafood processor Pescanova has installed two identical CO_2 racks at a plant in France, saving 20–26% in energy usage compared with its old f-gas system and an additional 10% from heat recovery.

That was the message from Hassan Abbou, Technical Sales Manager for German OEM TEKO in France, who spoke during the ATMOsphere Europe conference that took place online September 28–29, 2021. TEKO carried out the project in collaboration with French contractor MCI.

One of the main objectives for Pescanova was to obtain the French certificate of energy savings. It's a very "typical French administration" thing, Abbou explained, but something that is "really important for the industrial refrigeration segment." The certificate calculates the potential energy savings of a system. The amount of MW saved equals the amount of money one can potentially get back from the French government.

The cost of the installation was around €1.1 million (US$1.28 million), but "because of the structure and the way we did the engineering, the end user paid in total €0, so completely under subsidies," Abbou said. The installation project took 10 months: from April 2020 to January 2021. The main challenge was to remove all the old equipment to make way for the new system without interrupting the normal operations of the factory.

Pescanova sells packaged seafood, mostly shrimp, the focus of this application. Its fleet of more than 100 trawlers fish in the waters around Argentina, Peru and Uruguay in South America and around Mozambique, Reunion and Namibia in southern Africa. The company has 18 factories in 11 countries, including two in France and six in Spain.

How Pescanova processes seafood

The Pescanova factory in France has a production area of 4,500m2 (48,438ft2) and two processing lines that need cooling. One is a "deeping" line, where the shrimp are dipped directly in a saltwater tank. The other is a "trickling" line, which is more automated and has a conveyor belt moving the product along.

The shrimp caught by Pescanova's trawlers are cooled on the boats and delivered to the factory at -25 to -30°C (-13 to -22°F). At the factory, the frozen shrimp are stored in a -25°C cold room while the company awaits orders from customers, which are often restaurants and hotels.

When the orders arrive, the shrimp are defrosted with 35°C (95°F) hot water, which is produced by the waste heat recovered from the refrigeration system. The shrimp are subsequently heated and cooked. After cooking, the shrimp are first slowly "pre-cooled" with salt water until they reach 6°C (43°F). In the second cooling stage, the shrimp are cooled to 0°C (32°F).

The new installation is located outside in two 40ft (12.2m)-high containers next to each other. The old installation was a two-stage system using an R134a/ glycol chiller for the first stage and a pumped R404A system for the low-temperature stage. These two systems were replaced with two identical booster CO_2 racks, each with both medium-temperature and low-temperature capacity and a total refrigerant charge of 500kg (1,102lbs).

Each rack has a medium-temperature capacity of 250kW (71.1TR) at -11°C (12.2°F) and 125kW (35.5TR) low-temperature capacity at -38°C (-36.4°F), and each rack is equipped with two gas coolers. The system also has two evaporator stations with plate heat exchangers and total heat recovery.

The system is equipped with a 12,000L (3,170gal) hot water buffer tank designed with stratification, meaning that it has layers of water with different temperatures inside the same tank. The customer needs 25–35°C (77–95°F) water for defrosting, 35–45°C (95–113°F) water for processing and 75°C (167°F) water for cleaning and sanitary purposes.

The system also includes a smaller 2,500L (660gal) buffer tank with water for the cooling process. "This buffer tank is able to supply the right temperature when the customer needs it," Abbou said.

5.8 Grocery Outlet Specifies Transcritical CO_2 for New California Stores Following Energy-Efficiency Study

Transcritical CO_2 (R744) is now the refrigeration specification for new stores in California for Emeryville, California-based discount retailer Grocery Outlet, with a goal of expanding the application to other regions in the U.S.

This decision comes after a two-year monitoring program at an East Sacramento, California, Grocery Outlet store that opened in January 2020. The study found that the store's transcritical CO_2 booster system with an adiabatic condenser used 27% less energy compared to the R404A-based system of a similar store under the same brand.

The R744 system, manufactured by OEM Hillphoenix, also resulted in a reduction of energy costs by 23% and CO_2e emissions by 27%. The East Sacramento store is the first Grocery Outlet store to use transcritical CO_2 refrigeration; two more new stores in California, in Murrieta and Atwater, were scheduled to install the system by the end of 2022.

Details of the installation and Grocery Outlet's plans were presented by Frank Davis, Senior Director of Refrigeration and Sustainability at Grocery Outlet, during the "Measuring Performance of Natural Technologies" session at the North American Sustainable Refrigeration Council (NASRC)'s Sustainable Refrigeration Summit, which took place virtually October 24–28, 2022.

Results from the monitoring program were shared at the session by Safdar Chaudhry, Senior Engineer Manager at ADM Associates, which conducted the measurement and verification (M&V) analysis for the project.

R744 vs. HFCs

Grocery Outlet, which oversees 430 independently owned and operated stores across eight states, installed the CO_2 system in a 2,200m^2 (24,000ft^2) store in East Sacramento with funding from the Sacramento Municipal Utility District (SMUD) and the American Public Power Association (APPA)'s Demonstration of Energy and Efficiency Developments (DEED) program.

The CO_2 system uses 190kg (420lbs) of R744 and includes four compressors with a total capacity of 139.8kW (39.7TR) and one condenser with a capacity of 160.3kW (45.6TR). According to Davis, an adiabatic condenser was chosen to try to capture better energy efficiency and reduce energy costs. The total refrigeration load of the store's refrigeration equipment is 118.6kW (33.7TR).

To assess the benefits of the transcritical CO_2 booster system, its performance was compared to that of an HFC-based direct expansion (DX) system at a 2,155m^2 (23,200ft^2) Grocery Outlet store in the Pocket section of Sacramento.

The DX system uses 272kg (600lbs) of R404A – which has a 20-year GWP of 6,600 – and includes five compressors with a total capacity of 83.3kW (23.7TR) and five air-cooled rooftop condensers that have a total capacity of 127.1kW (36.1TR). The total refrigeration load of the store's 23 refrigeration cases of varying sizes and temperatures is 70.6kW (20.1TR).

Following a monitoring period from July 2020 until March 2022, the CO_2 system was found to be "superior to the conventional HFC system" in terms of energy use, energy cost and CO_2e emissions impacts, said Chaudhry during the NASRC event. The R744-based system used 27% less energy and reduced energy costs and CO_2e emissions by 23% and 27%, respectively.

During the M&V period, no leakage was reported for either system, which Chaudhry noted is very rare. However, if there was leakage at these stores, "the natural systems advantage would have increased significantly to a 93% reduction [in CO_2e emissions]," he added.

Analysis also found that while the installation and equipment cost for the CO_2 system was about 24% higher than a comparable conventional HFC system, operating costs of the former are estimated to be lower than for the latter.

In total, Grocery outlet received US$217,000 (€216,960) in funding for the project: approximately US$79,000 (€78,985) came from SMUD's natural refrigerant incentive fund, US$13,000 (€12,997) from the utility's energy efficiency incentive fund, and US$125,000 (€124,977) from an APPA DEED grant.

The money received was just enough to cover the additional cost of the transcritical CO_2 system versus a typical R448A DX rack, noted Davis.

5.9 California Dairy Farmer Installs PRO Refrigeration's CO_2 Chiller, Following Uncle's Example

South Creek Dairy, a dairy farm based in Earlmart, California (U.S.), last year finished commissioning a 100HP CO_2 (R744)-based chiller system from PRO Refrigeration, a 31-year-old company that specializes in packaged chillers for craft beer producers, wineries and dairy farms.

South Creek Dairy is owned by Christopher Jongsma, whose uncle Bill Jongsma was the first dairy farmer to install the "PROGreen" CO_2 chiller at his farm in Pixley, California, in 2021. It is considered the first chiller of its kind to be made in the U.S.

In 2022, Alaska-based microbrewery Denali Brewing and Spirits installed the CO_2 chiller to cool its ready-to-drink cocktails.

PRO Refrigeration, based in Auburn, Washington, partnered with San Joaquin Valley Dairy Equipment, a California provider of wholesale machinery and equipment for dairy farms, to install the chiller at South Creek Dairy, which uses it for cooling and heating applications.

"We owe a big thanks to both the Jongsma Family and the team at San Joaquin Valley Dairy Equipment for stepping up and partnering on these initial projects," said Jim VanderGiessen, PRO's CEO, in a statement."They are helping us prove that CO_2, or R744, is a real solution that dairy producers need to consider today."

The first phase of the installation included switching from an old chiller system to the new R744-based system. The first three milking sessions, with over 3,900 cows milked per session, proceeded with final milk temperatures of 37.5°F (3°C).

The second phase involved setting up the "PROHeat2o" Onboard Heat Recovery System. The teams worked together on an updated hot water piping strategy that heats water to 170°F (77°C) without using any propane or natural gas.

"The installation and startup of this chiller system went very smooth this week," said Ben Anders, Installation Manager for San Joaquin Valley Dairy Equipment. "Really, there were no major obstacles to overcome, and overall, this week has gone extremely well."

Learning about the system

Training has been a big part of the chiller's installation.

Christopher Jongsma, South Creek Dairy's owner, with his grandfather John, traveled to PRO's production facility in Mocksville, North Carolina, in July to learn about the system. Damon Reed, leader of the PROGreen Solutions team, introduced them to transcritical and subcritical CO_2 (R744) refrigeration and provided hands-on equipment training that included CO_2 safety. Christopher also made several visits to his uncle Bill's farm to view the system in operation.

"Damon and I talked about the value of the training sessions (in North Carolina) many times this week," noted Christopher. "To be involved as an owner and have an understanding of how the system operates and the fine-tuning, it has been a great experience."

Reed added that field commissioning of the system always starts off with a group training session, with many of the same technicians previously involved in the first CO_2 chiller project. "The group training allowed everyone the chance to get their questions answered and set the stage for a smooth commissioning this week," he said.

Two more PROGreen chiller projects are scheduled in the San Joaquin Valley, California, region.

In recognition of its CO_2 chiller, PRO received the 2022 EnVisioneer of the Year award from Danish manufacturer Danfoss last August.

5.10 Japanese C-Store Chain Lawson's First 100% Natural Refrigerants Store

In September 2019, Japanese convenience store chain Lawson opened its first freon-free store, which employs only natural refrigerant-based equipment.

Lawson, which operates more than 14,000 outlets, is one of Japan's top three convenience store chains, together with 7-Eleven and Family Mart.

The store is billed as an "environmentally friendly model store" that employs CO_2 and hydrocarbon refrigeration equipment. It is located on the Shonan Fujisawa Campus of Keio University, in Kanagawa Prefecture — about one and a half hours southwest of Tokyo by train.

The Keio University store is also Lawson's first to use hydrocarbons for its smaller plug-in upright and under-counter refrigerators as well as its ice makers.

Lawson has long been one of the world's leading end users of CO_2 systems, in particular CO_2 condensing units. It opened its first CO_2 store in 2010 and now operates more than 4,000 stores with CO_2 condensing units. However, Lawson has employed CO_2 mainly for its large applications, which include in-store refrigerated and frozen display cases.

Japanese OEM Hoshizaki supplied the hydrocarbon plug-in equipment while Panasonic provided the CO_2 equipment.

First Natural Refrigerants Store in China

In 2020, Lawson installed its first transcritical CO_2 and hydrocarbon-based cooling systems at one of its stores in Shanghai, China.

While some large-format supermarkets had installed transcritical CO_2 rack systems in China, this was thought to be the first transcritical CO_2 system deployed in a small-format food retail store in the country.

The use of transcritical CO_2 and hydrocarbon equipment at the Shanghai store is driven by Lawson's "commitment to fulfilling its corporate responsibility towards the UN Sustainable Development Goals — specifically goal 7 (affordable and clean energy) and goal 13 (climate action)," said Masaaki Kanbe, Director of Construction Headquarters for Lawson (China) Holdings.

In China, Lawson operates close to 2,000 stores spread across Beijing, Dalian, Shanghai, Chongqing, Wuhan and Hefei. More than half of these stores are located in Shanghai.

The new Shanghai store uses one Panasonic 2HP CO_2 outdoor condensing unit to supply cooling for one medium-temperature CO_2 display case inside the store. In addition, the store employs one propane-based plug-in ice cream cabinet. Kanbe said Lawson expects to see about 16% better energy performance, compared to conventional systems.

Installation went "smoothly and without any problems," said Kanbe, who credited prior and on-site technical guidance with making sure the installation of the CO_2 system went well.

5.11 Japanese Cold Storage Operator Again Sees Energy Drop with CO_2

Japanese cold storage operator Yoshio Ice Manufacturing & Refrigeration (Yoshio Ice) has seen a continued energy-use reduction with its second installation of a transcritical CO_2 (R744) refrigeration system.

The company presented operational data on the system during the ATMOsphere Japan 2021 conference, organized by ATMOsphere, publisher of this report.

In February 2020, Yoshio Ice retrofitted an existing R22 system with a "Super Green" CO_2 transcritical system at one of its cold storage facilities in Fukuoka, Japan. The CO_2 system, supplied by Tokyo-based manufacturer Nihon Netsugen Systems (NNS), began operating in April 2020.

For the period from April–December 2020, the facility saw a cumulative energy-use reduction of almost 22%, according to data presented by Yoshio Ice President Shigekatsu Koganemaru at the conference.

Yoshio Ice first installed transcritical CO_2 systems for one of its newly built cold storage facilities in Fukuoka in April 2018.

During the ATMOsphere Japan 2019 conference, NNS President Katsuhiko Harada presented energy performance metrics for this first installation from April–December 2018. Power consumption for the period was 27 kWh/m³, less than what was predicted (around 35 kWh/m³), and far less than Japan's industry annual average of around 61 kWh/m³.

It was these good results, Koganemaru said, that led the company to move forward with the most recent transcritical CO_2 installation in February 2020.

Controller's key role

In the latest installation, while CO_2 was a contributing factor to the energy drop, Koganemaru explained that the company's load-following inverter controller was the major factor in maximizing energy efficiency.

"The results of the installation of this equipment are not only due to the characteristics of CO_2 as a refrigerant," said Koganemaru. "It's the flexibility of our operation through advanced equipment control that makes these numbers possible."

The 2020 data told a seasonal story. In the summer, when the load was at its peak, there was little difference in the amount of electricity used compared to the original R22 system. In August, for example, the operating data showed only a 5.8% reduction in energy use.

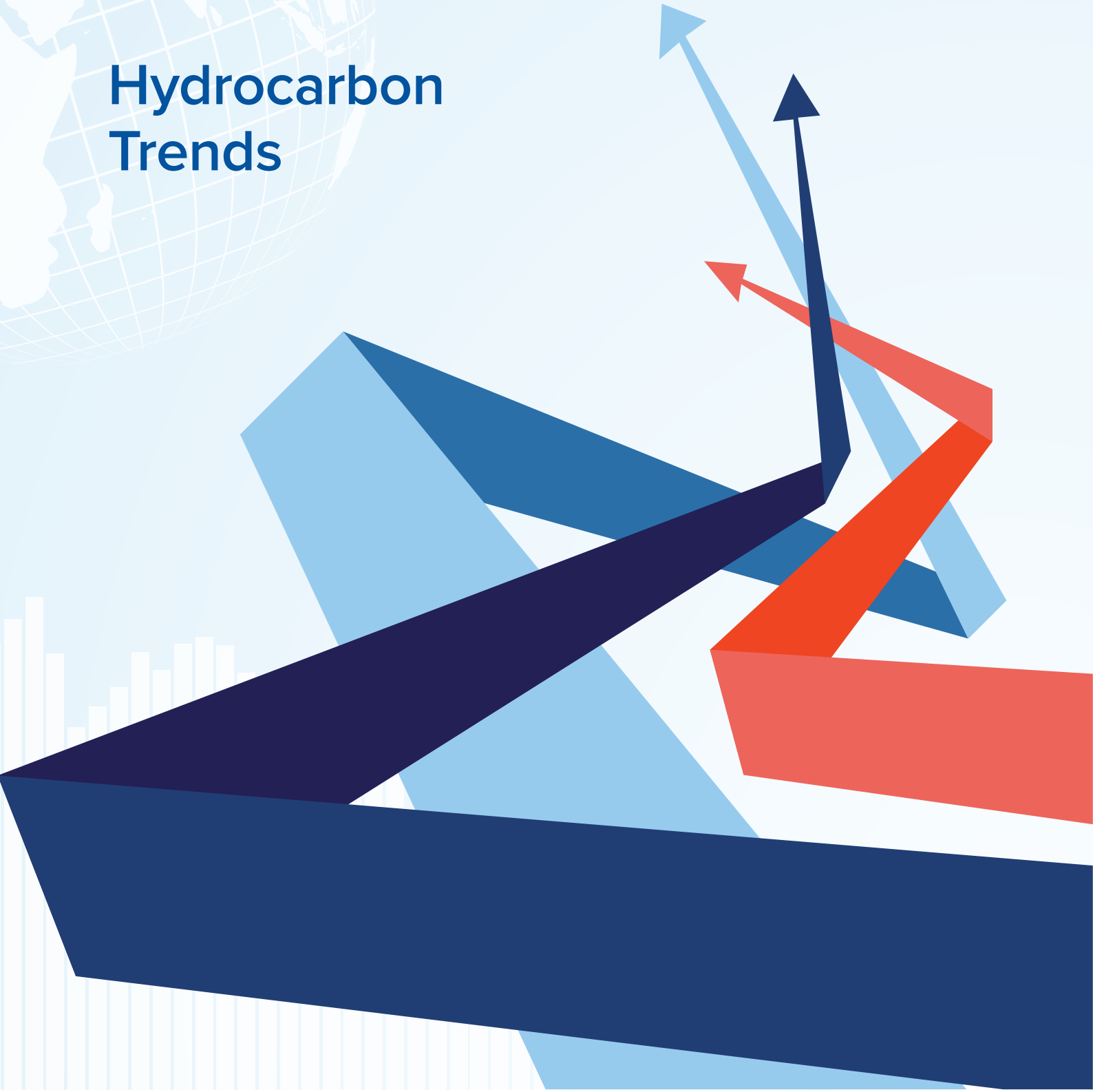
However, during winter, the inverter controls' impact on energy use became apparent. In particular, data for November 2020 showed a 38.8% reduction in energy use compared to the original R22 system. The CO_2 system, Koganemaru said, is also equipped with an inverter for the fan on the cooling side to increase efficiency and reduce the number of defrosts needed.

"Today, the technology being used for equipment efficiency and production processes is growing every day," said Koganemaru. "Since there is no significant difference in equipment efficiency, how to control them will be a major factor in improving COP [coefficient of performance]."

The Super Green CO_2 system, Koganemaru added, also employs a heat recovery system to store heat in a brine tank. The heat is then used for defrosting, further increasing the system's overall COP.

CHAPTER 6

Hydrocarbon Trends



6.1 Hydrocarbon Cases Play Many Roles

In supermarkets, "remote" refrigerated display cases have typically been linked through piping networks to compressor racks or condensing units outside of the sales area.

However, another option is so-called plug-in cases with internal condensing units that employ small amounts of hydrocarbon refrigerant, notably R290 or, to a lesser degree, isobutane (R600a) or propylene (R1270). These self-contained cases are typically easier and less expensive to install, maintain and replace than remote systems, allow flexible merchandising and offer low-energy consumption as well as residual heat reuse for the store's heating and hot water.

Notably, hydrocarbons represent a substantial and growing share of the refrigerants used in the marketplace. According to data from Embraco (a brand of Nidec Global Appliance), hydrocarbons accounted for 72% of the refrigerant market share, with HFCs taking up 18% in 2021; in 2025 hydrocarbons' share will grow to 83% and in 2030 to 96%, says Embraco.[158]

Most hydrocarbon cases are air-cooled, but a growing number, so-called semi plug-in cases, use a water-loop (glycol) system to remove the heat from lines of contiguous cases.

In large stores, R290 cases are employed as spot merchandisers – front-end beverage coolers or horizontal bunker cases – supplementing the central refrigeration system. They can also be used to replace outdated remote HFC cases – which improves the capacity of the HFC rack – as well as old self-contained HFC cases or be installed in an expansion/remodel. Thus, they are seen as an inexpensive way to shift a large store to natural refrigerants without investing in a new rack system.

In a growing number of small stores – including grocery, convenience, dollar and even drug stores – hydrocarbon units are being installed throughout the sales floor (and in a growing number of locations, in cold rooms). In Europe, chains like Waitrose in the U.K., Colruyt in Belgium and Germany-based Lidl have installed hydrocarbon units store-wide. In the U.S., Wild Fork Foods, a small Florida chain, is an example of a retailer that has taken this approach.

Some observers believe that many stores, particularly larger ones, will end up using a combination of CO_2 and R290, with CO_2 serving the perimeter and cold rooms, and R290 accommodating the center and front of the store. This would considerably reduce piping from the CO_2 rack system.

The hydrocarbon charge limit of 150g has not prevented the rapid expansion of the R290 display case market. However, the prospects for propane in commercial refrigeration improved when the International Electrotechnical Commission (IEC) increased the amount allowed in self- contained cases to 500g from 150g in 2019; this will potentially lower the cost of R290 equipment, particularly large cases. Regional standards bodies have adopted or are in the process of adopting the IEC model in whole or in part.

One of the leading global providers of self-contained R290 cabinets is Austrian OEM AHT, which has been making these units for more than 15 years. A new development is AHT's Active Monitoring System, which allows customers to monitor their cases to prevent food spoilage.

R290 in urban stores

In Europe, where many small-format stores have installed hydrocarbon cases throughout the sales floor, and often in the cold rooms, this trend will continue as more small stores are opened in urban areas. Large stores will use R290 cases in more places as a supplement to remote cases. In North America, a small but growing number of small-format stores are installing hydrocarbon cases throughout or in parts of the sales floor.

6.2 Variable-Speed Compressors Meet Efficiency Requirements

Variable-speed compressors for hydrocarbon cases were introduced in 2007. In the last few years, several compressor manufacturers have started expanding their variable-speed portfolios, adding hydrocarbon compressors for both small and larger applications.

In support of this trend, research and testing have found that variable-speed compressors can outperform conventional on-off systems in energy efficiency, temperature recovery time, noise output and operating temperature. Additional advantages of the variable-speed units include the ability to withstand network voltage fluctuations and reduced stress on a compressor's mechanical and electrical parts.

According to compressor manufacturer Embraco, a brand of Nidec Global Appliance, the market share of variable-speed compressors in plug-in hydrocarbon appliances was 18% (the rest being fixed speed) in 2021 and will grow to 30% in 2025 and 50% in 2030.[158]

Variable-speed compressor adoption is inevitable, says Embraco, in order to meet upcoming efficiency requirements around the world.

Embraco has presented several case studies supporting the benefits of switching to R290 variable speed. For example, using an R134a system with an on/off compressor as a baseline, a 1,120L (39.6ft3) R290 beverage cooler was able to achieve a 35.9% reduction in energy consumption. When adding a variable-speed compressor and R290, it achieved an even higher 53.4% energy reduction in comparison to the baseline.[159]

German manufacturer Secop has also found cabinet efficiency gains of 20–40% when switching a fixed-speed compressor to a variable. Variable-speed compressors previously made up 6%–7% of Secop's commercial compressor sales, but this share is growing, driven mainly by energy-efficiency regulations.[160]

According to U.S. manufacturer Tecumseh, its propane-based variable-speed compressor meets the requirements of the U.S. Environmental Protection Agency's (EPA) Energy Star "Emerging Technology" award.[161]

Global beverage producer Red Bull, by installing a variable-speed propane compressor in its refrigerated display cases in 2021, has reduced its energy consumption by 43% compared to its 2007 model and by 8% compared to its 2017 model.[162] The cases, supplied by Italian OEM EPTA Refrigeration, employ a variable-speed compressor with "Smart Drop-In" technology from Embraco.

While there is a cost premium for variable-speed compressors – about double the cost of fixed speed – there can be a quick ROI for the end user (in as little as three months).

Making hydrocarbons even better

By improving the efficiency of display cases, variable-speed compressors make hydrocarbon-based units even more attractive and generate a better return on investment and total cost of ownership.

6.3 Improved Heat Exchanger Design

Heat exchanger design is a constantly evolving science with new ideas of how to maximize heat transfer. MicroGroove technology is one of the latest ways of enhancing efficiency.

MicroGroove technology involves the use of smaller-diameter, specially enhanced copper tubes in heat exchangers. New systems based on these designs may give owners and engineers the opportunity to reduce operational costs and energy consumption, according to the U.S.-based Copper Development Association (CDA) in a 2020 report.[163]

Smaller-diameter copper tubes have been used in hydrocarbon systems requiring a small charge. In a paper presented at the 2018 Purdue Conferences, optimized domestic refrigerator condenser coils using hydrocarbon refrigerants were shown to deliver needed cooling capacity while using smaller-diameter (5mm/0.2in) MicroGroove copper tubes that contain a small charge of refrigerant.[164]

Israeli heat-exchanger manufacturer Lordan Coils has developed a cold-climate R290 residential heat-pump water heater (HPWH), using 5mm MicroGroove copper tubes to achieve a low charge.[165] The MicroGroove 5mm copper tubes are used to create bent L-shape heat exchanger coils with high heat-transfer coefficients, resulting in higher seasonal energy efficiency ratios (SEER). The small-diameter tubes mean less material is needed, giving lower system weight while maintaining the same capacity.

The International Copper Association (ICA) has released new design and simulation software for heat exchangers that use small-diameter MicroGroove tubes. The software – HXSim "Small Diameter Copper Tube Air Conditioning Heat Exchanger Simulation Tool" Version 3.0 – can be freely downloaded online.[166]

Cutting cost, charge

MicroGroove tubes could help reduce the cost of hydrocarbon-based self-contained display cases, improving efficiency and keeping charges to a minimum.

6.4 Hydrocarbon Chillers for Industrial Applications

In recent years, hydrocarbons, known mainly for their application in commercial display case refrigeration, have found growing employment in industrial chiller applications.

For example, Secon, a German manufacturer, was founded in 2010 with the aim of manufacturing chillers solely on the basis of natural refrigerants and became one of the first companies to develop production-ready hydrocarbon chillers.[167]

Throughout the German-speaking region, Secon has become a key player in this expanding market segment.

In addition to manufacturing a range of propane (R290) chillers, Secon utilizes propene (R1270) and isobutane (R600a) refrigerants in its products and offers subcritical CO_2 refrigeration systems and machines with air-cycle technology. The manufacturer has many industrial customers for its hydrocarbon-based chillers, including a German brewery[168] and a large German retailer.[169]

Secon's industrial hydrocarbon chiller range in capacity from less than 100kW (28.4TR) to more than 500kW (142TR).

Hydrocarbons are considered highly feasible in all temperature ranges except low-temperature applications (-15 to -30°C/5 to -22°F), where its use is possible but not necessarily the best choice, according to Joachim Schadt, General Manager at Secon.[170]

Another major hydrocarbon chiller producer is Spanish manufacturer INTARCON.[171] In February 2022, the company announced several new propane-based products in its new industrial product catalog for 2022–2023. Intarcon also produces R290 industrial refrigeration monoblocks for large cold storage facilities and workrooms, such as the Superblock R290.

Italian OEM Euroklimat produces large-capacity R290 chillers. In 2021 a French dairy chose three R290 chillers from Euroklimat for a cheese production site.[172] The of the units have a combined cooling capacity of 330kW (93.8TR), while the third has a cooling capacity of 158kW (44.9TR).

On the smaller-capacity side, Italian process-cooling and air-conditioning manufacturer MTA released a series of air-cooled industrial chillers using R290 refrigerant in March of 2022. Called the TAE N Mini series, the chillers come in four models, with cooling capacities from 1.7kW (0.48TR) to 4.4kW (1.3TR) and water outlet temperatures ranging from 0°C (32°F) to 30°C (86°F).[173]

The MTA chillers can serve a wide array of process cooling applications, including food and beverage, wineries, plastics, chemicals, pharmaceuticals, lasers and machine tools. Using "an extremely low refrigerant charge," the chillers can be installed indoors, said MTA.

Competing with CO_2, NH_3

Look for hydrocarbon chillers to increasingly compete with CO_2 and low-charge ammonia systems for market share in the industrial space.

6.5 Dutch Supermarket Chain Fits Latest Store with Freor R290 Cases and Hydroloop

Last year Dutch supermarket chain Boon's Markt, part of the Boon Food Group, fitted its newest store in the village of Wolphaartsdijk with propane (R290)-based refrigeration display cases from Lithuanian manufacturer Freor.

The units are from the manufacturer's Green Wave R290 product range and operate on a hydroloop glycol system that removes the heat of condensation.

Freor, which announced the installation in August 2022, is a major supplier of R290 display cases, both air- and glycol-cooled, to European supermarkets for complete-store layouts.

Having made a commitment to maintain product freshness in the most efficient way, Boon's Markt wanted an "environmentally friendly cooling solution," and Freor's R290-based system was the perfect fit, according to a recent statement from the manufacturer.

"[We are] committed to offering only top-quality commercial refrigeration solutions with the newest technologies, based on the latest R&D, putting the emphasis on the great presentation and preservation of merchandise," said Freor.

Boon's Markt has installed a range of Freor cases to provide its customers with a variety of products.

For medium temperature, the supermarket opted for Freor's JUPITER multideck refrigerator units with glass doors, which provide "outstanding product presentation" and ensure freshness due to the balanced circulation of cold air between the shelves, according to the manufacturer.

Freor's VEGA QB H2 multi-level self-service refrigerated counters were also selected. These units include design features that maximize product freshness, such as protection against glass fogging and even allocation of cool air throughout the display area, said Freor.

To meet the supermarket's low-temperature requirements, Freor's ERIDA upright freezers preserve frozen products at temperatures of -18 to -21˚C (-0.4 to -5.8˚F), and -22 to -24˚C (-7.6 to -11.2˚F). The units include an anti-condensation foil to prevent fogging. According to the manufacturer, "cooling is expertly distributed throughout the inner spaces between the freezer shelves to provide an even temperature for all frozen merchandise."

Boon's Markt also chose Freor's wide dual-compartment HELLA freezer island. Its "high panoramic glass lids" offer clear product visibility and reduced energy consumption, said Freor. A special defrost heater inside the freezer helps prevent buildups of frost and ice, ensuring better product preservation, the company added.

According to Freor, the HELLA R290 model "is a great choice for future-oriented retailers switching to green refrigeration."

Freor's Netherlands partner, Koelservice Van Tol, installed the supermarket's new system.

6.6 Hannaford Equips Fifth Store with R290 Cases for Frozen-Food Line-up

U.S.-based supermarket chain Hannaford has equipped the entire frozen section of its new store in Brunswick, Maine, with propane (R290) self-contained cases, according to a presentation by Harrison Horning, Director of Maintenance, Retail Business Services – Hannaford and Stop & Shop, part of Ahold Delhaize.

The presentation was made during the ATMO America conference last year in Alexandria, Virginia. The conference was organized by ATMOsphere, publisher of this report.

In addition to the 120 doors of frozen food and ice cream R290 display cases, the setup includes a water-cooling loop that contains a 35% propylene/glycol mix and removes condensation heat from the freezer units. This heat can either be transported to the store's rooftop where it is dispersed to the air in a fluid cooler, or it can go via the loop's diverting valves for heat reclamation. The overall system, called Micro DS, is provided by U.S. manufacturer Hussmann.

Hannaford's Brunswick store, which opened in June 2021, is the fifth of the chain's new stores to adopt this frozen-food refrigeration architecture. It demonstrates how R290 cases can be used across large sections of a store, or an entire store, as opposed to individual spot units.

Hannaford was planning to adopt a similar approach in existing stores for the first time in two projects in 2022.

The retailer also has the distinction of being the first chain in the U.S. to install a CO_2 (R744) transcritical system in 2013 at its store in Turner, Maine.

When asked whether there was a preference between CO_2 and R290, Horning said that both refrigerants have their advantages and disadvantages.

"CO_2 tends to be complicated in remote areas where technician support is limited," said Horning. "With R290, you can lose one condensing unit, and it still holds temperature, so it's not an emergency call and might be a better bet from a reliability point."

"I don't think there's a right or wrong," continued Horning. "You can [use] either of these solutions in an existing store; both are compatible with medium-temperature glycol, and you can do CO_2 for low temperature."

Lessons learned

During Horning's presentation, he looked at four aspects of the store's R290 setup: cost, reliability, sustainability, and maintenance and training.

For new stores, Horning said that costs are either the same or lower, than a rack system, depending on freezer design. Despite the R290 cases being more expensive than remote cases, retailers save costs by not needing a rack. Horning also pointed out that some retailers may be willing to spend more money "if it's an effective way to reduce greenhouse gas emissions." This is the case with Hannaford's Retail Business Services, which is striving to achieve net-zero greenhouse gas emissions by 2040.

Reliability is the most important thing, according to Horning. He rated system performance as "generally acceptable," with lower than 7% failure during the first year. Emphasis was placed on not cutting any corners during installation – flushing, filling, venting, flow balance etc. – to reduce risk.

In terms of sustainability, refrigerant emissions are negligible for this part of the system, and gas heating requirements can be reduced through heat reclamation. Electricity demand may increase slightly due to the system's pumps, but this is also negligible, according to Horning.

The system requires R290, water/glycol and on-board controls training.

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CHAPTER 7

Ammonia Trends

7.1 Low-Charge Ammonia

Over the past five years, low-charge ammonia systems, driven by safety and regulatory considerations, have gained traction in cold-storage and food-processing applications – a trend that is expected to continue throughout the world.[174]

The low-charge systems have taken the form of single or multiple packaged units, typically installed on or near rooftops, or centralized, machine-room systems. The latter could also include ammonia/CO_2 cascade or systems that confine the ammonia to the machine room and use a secondary refrigerant for the refrigerated space. All models take advantage of the inherent efficiency of ammonia as a refrigerant.

These systems have allowed many industrial end users to dramatically cut the amount of ammonia used, compared to traditional liquid-overfeed systems, thereby reducing their safety requirements, while maintaining – or even improving upon – the high efficiencies of traditional ammonia systems.[175]

An example of the growth in low-charge ammonia can be seen in U.S. OEM Evapco, which recently reported that, since introducing its Evapcold low-charge ammonia packaged units in 2016, it has installed 150 of the units across 30 industrial sites in North America, with each site using between one and 10 units.[176]

Evapco low-charge packaged ammonia refrigeration units installed at cold storage warehouses in Sioux Falls, South Dakota (U.S.), and Hamilton, Ontario (Canada), were found to have low Specific Energy Consumption (SEC) values, indicating their high level of efficiency.[177]

The amount of ammonia in low-charge systems varies. Among the lowest charges was devised by Professor Pega Hrnjak of the University of Illinois at Urbana-Champaign and manufacturer Creative Thermal Solutions (CTS), who developed a system using only 0.1lb/TR (0.01kg/kW) of ammonia and with very low-cost components.[178]

Stefan Elbel, CEO of CTS, reported in 2022 that a two-phase ammonia recirculating ejector for liquid overfeed systems can improve the capacity and COP of an ultra-low-charge ammonia chiller by 28% and 22%, respectively.[179]

Low-charge packaged systems, paired with glycol, are also being used as chillers for processing or comfort cooling in industrial spaces. The chillers come in both water- and air-cooled configurations, the latter being lower cost and easier to install.

In 2016, the International Institute of Ammonia Refrigeration (IIAR) revised its widely respected IIAR-2 safety standard for ammonia, for the first time addressing ammonia equipment outside the machine room such as low-charge ammonia packaged systems, as well as explicitly covering ammonia/CO2 systems.[180]

In November 2018, IIAR released Low Charge Ammonia Refrigeration Management (ARM-LC), its first guidelines for users of low-charge ammonia systems that use a charge of 500lbs (227kg) or less.[181] The guidelines, which covers packaged and centralized low-charge ammonia systems, are designed to help end users of low-charge systems that may not have used ammonia before.

One of the key advantages of low-charge ammonia systems is that they enable end users to avoid demanding federal regulations on ammonia safety. For example, in the U.S., operators of low-charge systems can abide by the General Duty Clause, which is far less restrictive than stringent rules established by the Environmental Protection Agency (EPA) and the Occupational Safety and Health Administration (OSHA).

Greater comfort level

Low-charge ammonia is bringing ammonia technology into the 21st century, unlocking opportunities for ammonia beyond its traditional market. End users who were previously hesitant to switch to ammonia now have peace of mind thanks to the vastly reduced refrigerant charge and perceived risks. This is expected to lead to the increased uptake of ammonia systems, even in regions where its use has been declining or not popular in the past.

7.2 Ammonia in Supermarkets

The number of supermarkets that use ammonia-based refrigeration systems in concert with CO_2 and possibly glycol as a secondary fluid is quite low – probably under 20 worldwide. In the U.S., for example, there are only five stores with these systems while in Europe, there are three (and possibly more).[182, 183]

The reason for this is twofold: fear and cost. The fear stems from ammonia's toxic properties as well as the noxious odor it exudes; an ammonia leak is not something that most grocers would happily contemplate. Their assumption is that local building authorities are also not kindly disposed toward ammonia systems.

As for cost, ammonia/CO_2 systems typically run 150% higher than that of conventional DX supermarket systems.[182]

However, it turns out that because the amount of ammonia used in supermarket systems is minimal and confined to the machine room or on the roof, local fire marshals don't typically have a problem with it. Moreover, in many cases, these systems have been found to be extremely efficient, saving the retailer a considerable amount in electricity costs.[107]

In the U.S., the most recent installation of an ammonia/CO_2 system was in April 2020 by Raley's at a new 55,000ft^2 (5,109.7m^2) store in Sacramento, California.[184]

The ammonia/CO_2 system that Raley's selected for this initial installation is different from those used by the other four U.S. stores in several respects. One is the way CO_2 is employed. While the other stores use a cascade system that includes CO_2 compressors for low-temperature cases, Raley's has opted for a CO_2 compressor-free pumped liquid-overfeed system. (Raley's and the other systems all use pumped overfeed for medium-temperature cases.)

More ammonia stores coming?

Ammonia/CO_2 systems will likely remain a niche application in supermarkets. But if the safety record of the pilot stores remains positive and their energy savings become better known, they may yet become a significant factor in the marketplace.

7.3 Despite COVID-19, U.K. Dairy Installs Low-Charge Chiller, Boosting Production and Efficiency

When First Milk, a farmer-owned dairy co-operative base in Glasgow, Scotland, decided to replace an aging chiller at one of its two creameries in 2020, it didn't allow the COVID-19 pandemic to stand in its way.

Owned by the family farms that supply it with milk and invest capital in the business, First Milk produces cheddar, regional cheeses and dairy ingredients, as well as marketing fresh raw milk to many other U.K. dairy processors. Its Lake District Creamery, located in Aspatria, Cumbria (northwestern England), produces cheddar under the Lake District Dairy Co. brand, as well as for its own-label retail customers.

In 2021, the creamery's R404A refrigeration system in its "rapid cool store (RCS)" was approaching the end of its life. So First Milk decided to replace it with a low-charge ammonia Azanechiller 2.0 system, provided by Glasgow-based Star Refrigeration, which described the installation on its website.[185] The cooling system was part of a £3.5 million (US$4.8 million) investment First Milk made in upgrading the creamery in order to help meet its net-zero carbon agenda.

In the RCS, the cheese enters with a core temperature of approximately 30°C (86°F) and is held for 18 hours to reduce the core temperature to 12°C (53.6°F) before being palletized and stored.

The modular air-cooled Azanechiller, which uses only 42kg (92.6lbs) of ammonia, has delivered some tangible benefits, reported by Star. For example, the unit works in conjunction with the chilling tunnel to enable the creamery to increase its cheese output by just under 30%.

In terms of efficiency, the Azanechiller has improved operating efficiency by about 25% compared to new refrigeration systems using HFCs and HFOs, Star said.

In addition, First Milk's new Azanechiller 2.0 exceeds the "Minimum Energy Efficiency Requirements" set by the Ecodesign for Energy-Related Products Regulations – the U.K. instrument that domestically implements the European Ecodesign Directive – by 75.2%.

"The Azanechiller 2.0 boosts the capacity of the chill store plant and offers great efficiency by delivering immediate reductions on our energy costs," said Ian Wilson, Project Engineer for First Milk. "This development also helps towards our First4Milk net-zero commitments, delivering more efficient and environmentally friendly refrigeration."

This installation was carried out during "the most constrictive COVID-19 restrictions," said Star. However, delivery of the equipment to the site was not affected, and Star maintained its usual lead times.

"Star worked with its suppliers, staff and customers to minimize the effects of the virus and deliver on pre-COVID time frames and with all the necessary health and safety requirements," Star said. "The 'plug and play' feature of the chiller ensures the on-site installation time is kept to an absolute minimum and the unit is ready for operation as soon as possible."

Star had installed the R404A chiller in 1985, so it was familiar with the operation. "It's nice to work with them again as they understand our requirements and can inform us of the new technology available since the original install," said Wilson.

“Updating our rapid cool store was phase three in our four-phase strategic plan to increase capacity significantly, and Star proposed a safe, efficient and reliable option,” added Wilson.

The Azanechiller 2.0 is manufactured and run-tested at Star’s production facilities in Glasgow before being delivered to site, charged and ready to commission. Installation is “simple,” said Star, requiring a suitable base concrete/steelwork, connection of secondary pipework and an electrical power supply.

First Milk was able to attend one of Star’s manufacturing sites in Westway, Scotland, in order to check the Azanechiller 2.0 live.

First Milk took a two-year warranty, two-year maintenance plan and dial-out service for preventative maintenance so that Star’s aftercare engineering team can “remotely interrogate the plant to ensure it is running as expected,” said Star.

7.4 Low-Charge Packaged Ammonia Systems Found to Be Very Efficient

Low-charge packaged ammonia/NH_3 (R717) refrigeration units installed at cold storage warehouses in Sioux Falls, South Dakota (U.S.), and Hamilton, Ontario (Canada), were found to have low Specific Energy Consumption (SEC) values, according to Kurt Liebendorfer, Vice President at Evapco, and Rob Adams, Principal at Ti Cold, who described these installations during a case study session at ATMO America in June 2022.

The conference was organized by ATMOsphere, publisher of this report.

Evapco supplied the ammonia units, and Ti Cold built the facilities for Lineage Logistics in Sioux Falls and Sierra Supply Chain Services in Hamilton.

The high energy efficiency of the low-charge packaged ammonia units is reflected in the SEC. A good historic SEC benchmark for a warehouse has been 1kWh/ft³/yr (35.7kWh/m³/yr), Liebendorfer explained. For the Sioux Falls facility, the freezer rooms have an SEC of 0.55kWh/ft³/yr (19.6kWh/m³/yr) and the convertible rooms an SEC of just 0.28kWh/ft³/yr (10kWh/m³/yr). When operating in full blast freezer mode, it has an SEC of 1.13kWh/ft³/yr (40.4kWh/m³/yr), which is "very, very good, given that blast operations are very heavy loading," said Liebendorfer. The SEC of the Hamilton cooling system is very "attractive" at just 0.37kWh/ft³/yr (13.2kWh/m³/yr).

According to Liebendorfer, centralized ammonia systems have SECs typically between 0.75kWh/ft³/yr (26.8kWh/m³/yr) and 1kWh/ft³/yr. "We have seen the low-charge packaged system go lower than that because you have more compressors and they are all VFD controlled, there's better turn down," said Liebendorfer.

Stefan Jensen, Managing Director of Scantec Refrigeration Technologies, Brisbane, Australia, has reported that a centralized DX ammonia delivers SECs of between 20kWh/m³/yr (0.57kWh/ft³/yr) and 24kWh/m³/yr (0.68kWh/ft³/yr) when serving a distribution center with a refrigerated volume of 40,000m³ (1,553,845ft³).

Sioux Falls

The Sioux Falls facility was an expansion project with 134,000ft² (12,449m²) of new cold rooms, for a total size of 464,000ft² (43,107m²). The expansion has a refrigeration load of 540TR (1,899kW) with -10°F (-23°C) freezers and -10°F/35°F (1.7°C) convertible rooms.

The facility, bought recently by Lineage Logistics, turned out to have insufficient capacity, and the expansion plans then left Ti Cold with a choice either to build a new engine room or go for low-charge packaged ammonia units, with the latter option ultimately prevailing. The expansion was finished in January 2022.

Ti Cold and Lineage went with eight large penthouse LCR-P dual compressor air-cooled packages from Evapco. The installation includes six units of 70TR (246kW) capacity (at -20°F/-29°C suction temperature), and two units of 60TR (211kW) capacity, both types with an ammonia charge of less than 500lbs (227kg), giving them a charge of 7.4lbs per TR (0.95kg/kW). With a 4,000lbs (1,814kg) total charge, the system required much less ammonia than a traditional centralized system. "Had this been a traditional plant, the charge could well have approached 10,000lbs [4,536kg]," Liebendorfer stated.

Hamilton

The Canadian storage facility uses the same style penthouse units as the Sioux Falls facility, though with single compressor packages. Sioux Falls uses double compressor packages. In Hamilton they have

installed five rooftop penthouse ammonia units, and a sixth unit is a low-charge ammonia glycol chiller. “Penthouses are great for big rooms and cold temperatures, but they are too expensive for small rooms or higher temperatures,” Liebendorfer explained.

The Hamilton facility is 250,000ft^2 (23,226m^2) and includes a 30,000ft^2 (2,787m^2) food processing space. Total refrigeration load is 517TR (1,818kW) with -10°F freezer rooms and 35°F cold rooms, processing room and docking area. The cooling system has a total of 2,257lbs (1,024kg) charge, which equals just 4.4lbs per TR (.59kg/kW). Current freezer load is around 250,000lbs (113,398kg) per day, but the system is designed so the amount can be increased to 500,000lbs (226,796kg) per day. Construction was expected to be completed last July.

30 CO_2
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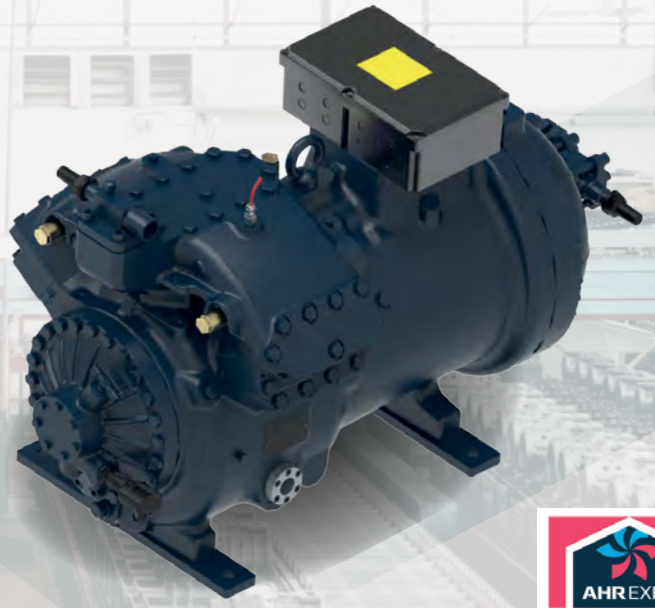

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CHAPTER 8

European Market Data: Stores Using Natural Refrigerants

8.1 Total Addressable Market

In 2021, there were an estimated 272,100 food retail outlets, including supermarkets, hypermarkets, grocery, discount and convenience stores in Europe. In this report, Europe is defined as including the EU, U.K., Norway, Switzerland, Iceland, non-EU Balkan states, Ukraine, Belarus, Moldova and the European part of Russia.

In 2022, we adjusted our estimate to be 299,025 food retail outlets, a difference of 10%.

Based on feedback from a sample of key retail end users, stores are retrofitted on average every 10–20 years, depending on each retailer's individual policies. In Europe, particularly, the retrofit market offers great opportunities to switch to natural refrigerants, with many retailers having done so already.

8.2 Transcritical CO_2 Racks and Condensing Units

Background

Europe has long been a major source of natural refrigerant innovation in the HVAC&R sector. It is thought that Norwegian scientist Gustav Lorentzen created the modern age of natural refrigerants in the late 1980s when he developed the modern transcritical cycle for CO_2.

By the 2000s, supermarkets were beginning to use CO_2 refrigeration systems. In 2001, Sergio Girotto, now president of Italian OEM Enex (which he founded in 2004), installed the first transcritical CO_2 multi-compressor system at a Bingo supermarket in Cornuda, Italy.[186]

But Europe's natural refrigerant development did not take off until the arrival of the EU's F-gas Regulation, first announced in 2006, revised in 2014, and under revision again. (Read more about this regulation in chapter 1.3.)

An important trend supporting the growth of transcritical CO_2 in Europe and worldwide is the development of technologies that enable efficient operations of the systems in warm-ambient climates, including ejectors, parallel compressors, adiabatic gas coolers, subcooling devices, pressure-exchanger devices and Epta's FTE and ETE systems. (See chapter 5.2.)

The Market Today

According to data collected by ATMOsphere, there were 140 stores with transcritical CO_2 systems in Europe in 2008. By 2013, that number had grown to 2,885 and then almost doubled to 5,500 in 2015. In 2017, the number had more than doubled to 12,000, and almost doubled again to 23,000 in 2019.

Of the 29,000 transcritical CO_2 installations in Europe as of March 2020, 27,550 (95%) were estimated to be food retail stores. Of these installations, 3.9% (1,074 stores) were using transcritical CO_2 condensing units. The rest employed a centralized system (one or more racks). There were 1,450 industrial sites using transcritical CO_2 systems.

As of March 2021, the number of food retail stores using transcritical CO_2 systems in Europe was estimated to be 38,400. There were 1,640 industrial sites using transcritical CO_2 for a total of 40,000 transcritical CO_2 sites in Europe.

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Based on a survey of key OEMs in 2022, we determined that the estimated number of food retail stores employing transcritical CO_2 refrigeration had grown significantly. We now estimate that, as of September 2022, there are 55,000 stores with transcritical CO_2 systems in Europe, including 50,000 using a centralized system (racks) and 5,000 using condensing units. There are an estimated 2,000 industrial sites using the technology, for a total of 57,000 total transcritical CO_2 sites.

This equals a food retail market penetration of 18.4% – the percentage of all food retail stores in Europe estimated to feature transcritical CO_2 installations, up from 14.1% in 2021.

8.3 Hydrocarbon Self-Contained Cases

Background

While CO_2 systems represent the largest share of natural refrigerant-based refrigeration in European supermarkets, equipment using hydrocarbons – mostly propane (R290), but also propylene (R1270) and isobutane (R600a) – is another widely employed application. In contrast to CO_2, typically used in racks or condensing units supporting separate display cases, hydrocarbons are mostly used in self-contained plug-in display cases, either air-cooled or water-cooled (via water/glycol loop systems). Hydrocarbons, not CO_2, have become the de facto natural refrigerant for self-contained plug-in units.

In the modern era of refrigeration – post-1990 – hydrocarbons were the first natural refrigerants to gain major traction in the marketplace, but in the domestic, not commercial, sector. In 1992, global NGO Greenpeace spearheaded the development of the "GreenFreeze" home fridge, which uses no more than 150g of R600a. Initially available in Germany, GreenFreeze gained rapid acceptance in Europe and other locations, and today about 1 billion of the fridges are installed worldwide, according to Greenpeace.

By the 2000s, self-contained plug-in hydrocarbon refrigeration began to catch on in European supermarkets, with R290 the most commonly used refrigerant and R600a in smaller cases.

The first air-cooled R290 retail display cases appeared in 2004. Until about 2012, most of the R290 cases were ice cream chest freezers from brands like Unilever and Nestlé.

The first semi-plug-in display cases (with a waterloop system to remove heat) appeared in 2014, followed by the first multi-deck R290 freezers.

Today, self-contained propane waterloop systems are enjoying wider uptake in commercial refrigeration applications globally – particularly in Europe, where manufacturers such as Freor have installed numerous waterloop systems.

In Europe, there are more opportunities to install R290 cases than in the U.S. – more stores use them throughout the sales floor, there are more small stores, and there is more conversion to natural refrigerants and more use of horizontal cases. Europe is at least five years ahead of the U.S. in the use of hydrocarbon cases.

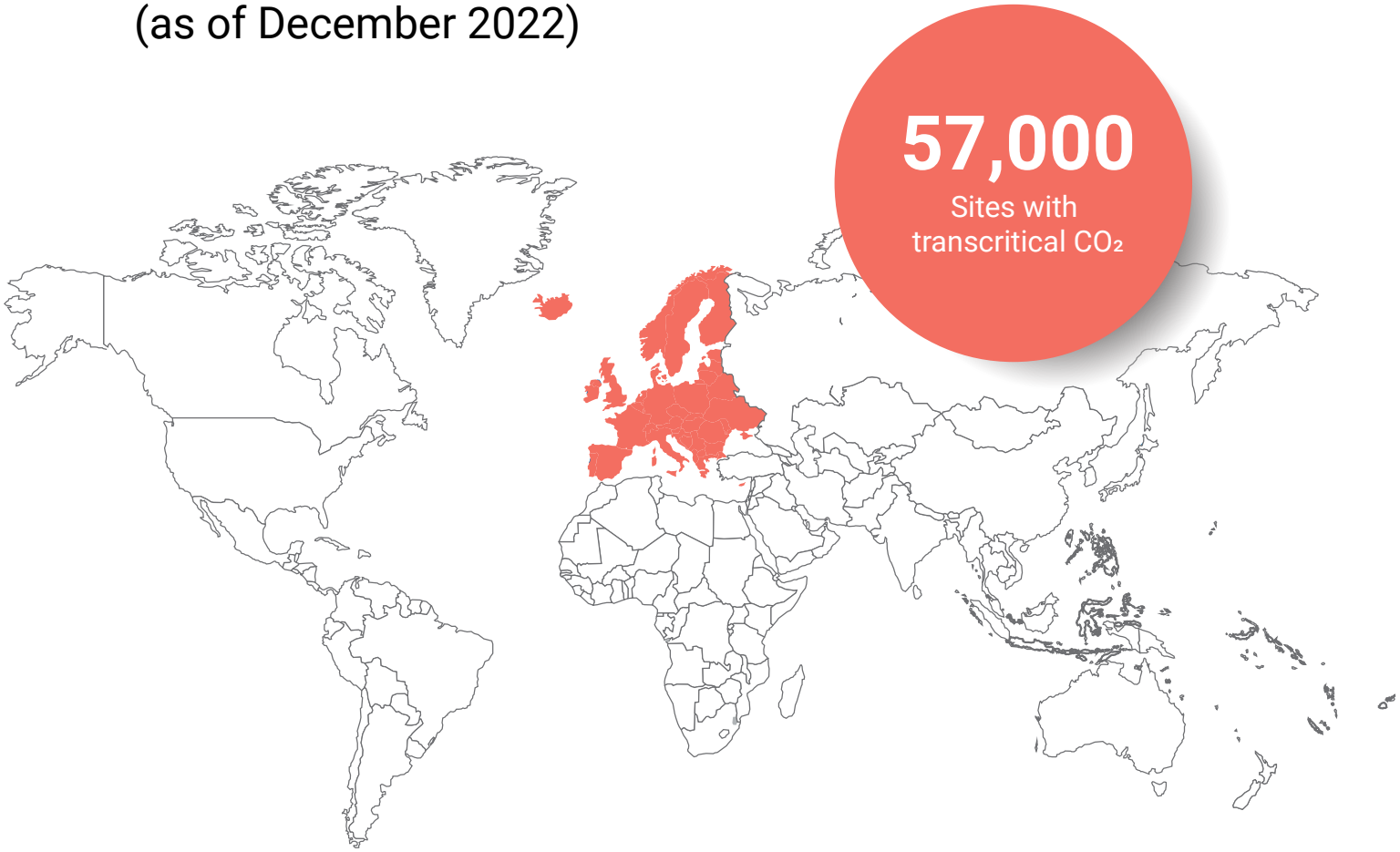
The Market Today

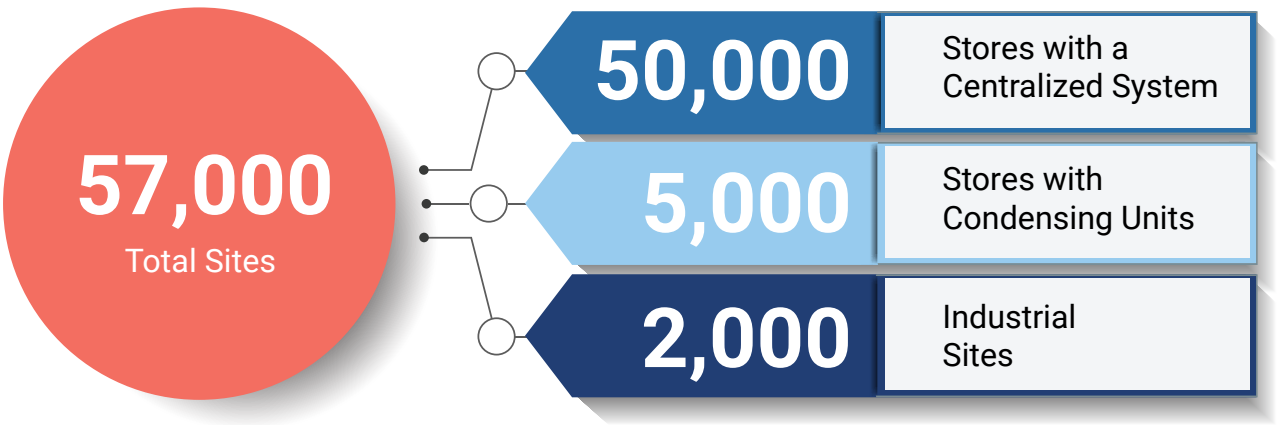
As of June 2021, there were an estimated 2.7 million hydrocarbon-based store refrigeration cases in operation in Europe, based on production numbers from leading OEMs. This number also included an estimated 300,000 units beverage coolers.

Based on a survey of hydrocarbon cabinet OEMs, there were an estimated 2.9 million cases installed at European stores at the end of 2022, a net increase of about 200,000 cases from June 2021.

Transcritical CO_2 Installations in Europe

(as of December 2022)





ATMO sphere

Transcritical CO_2 Commercial Refrigeration Market Penetration in Europe

299,025 total stores

18.4% transcritical CO_2 stores

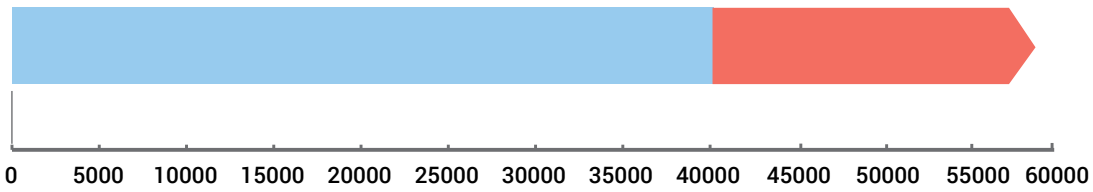
Transcritical CO_2 installation growth in Europe

(stores and industrial facilities)

2021 **40,000**

2022 **57,000**

Growth from March 2021 to December 2022 (21 months)



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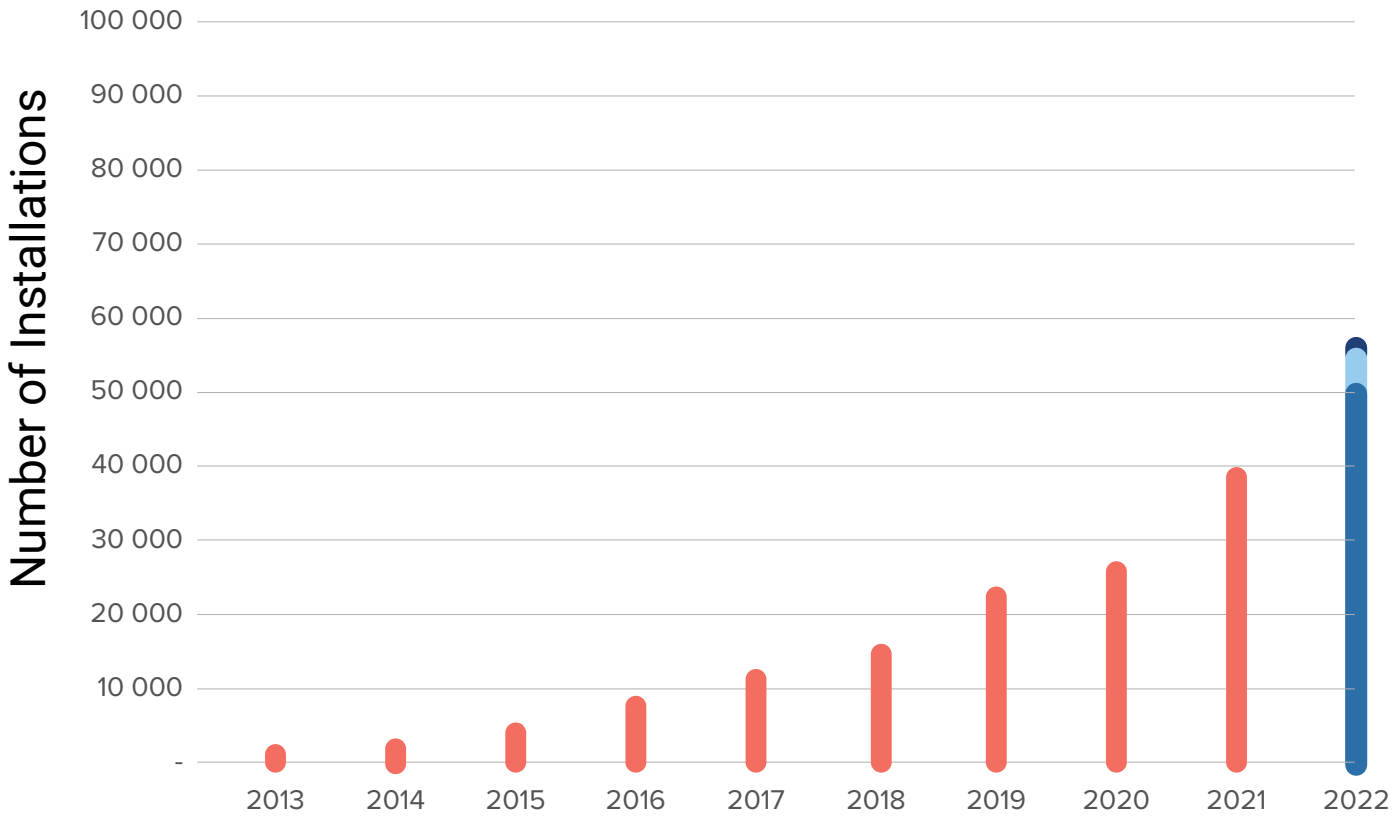
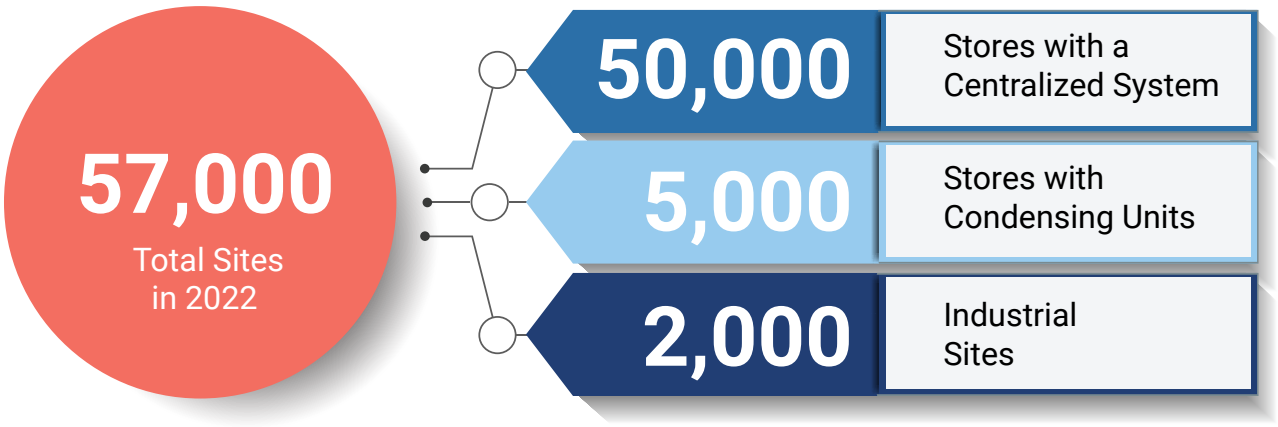
Transcritical CO_2 Installation Growth in Europe

(stores and industrial sites)

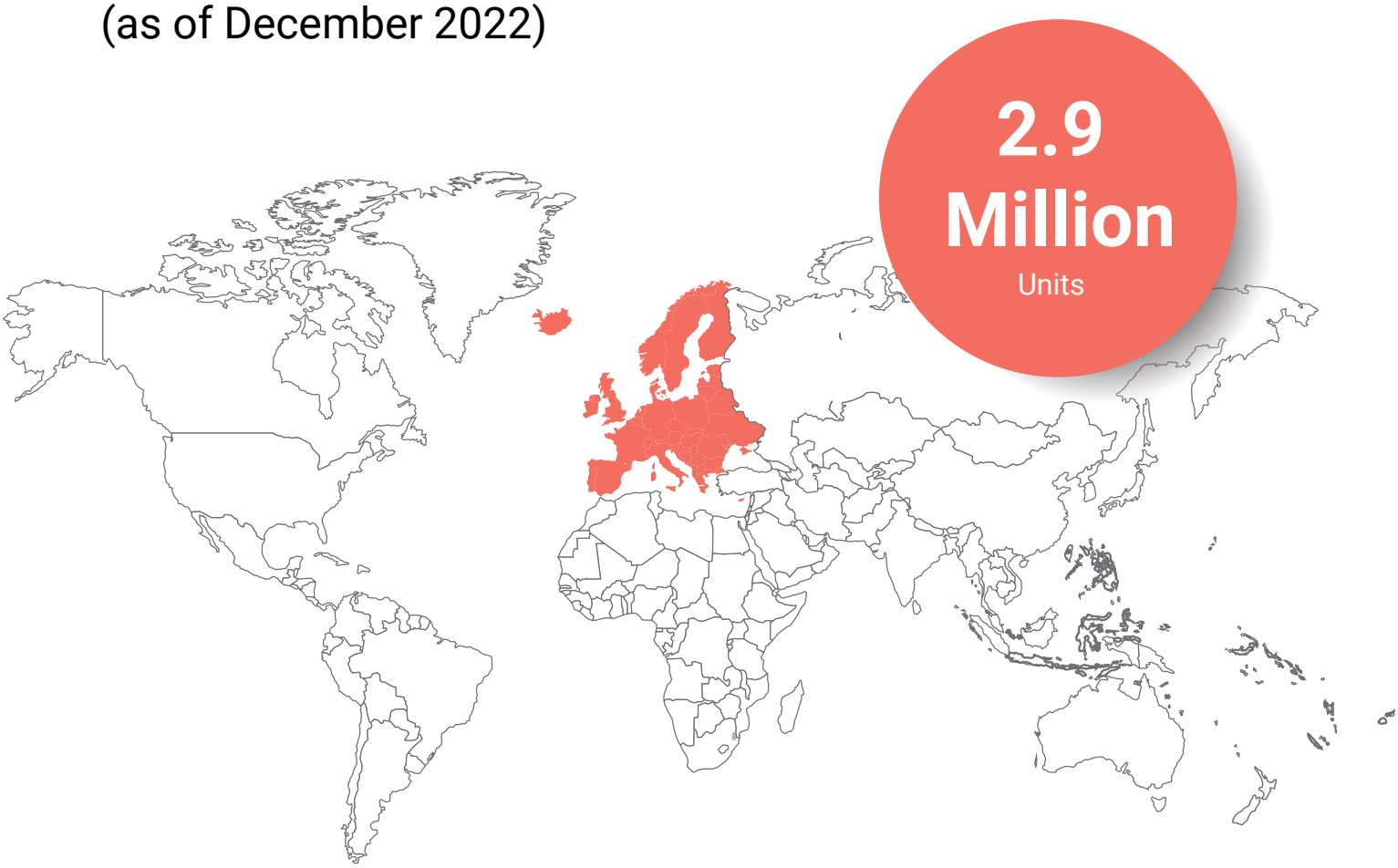


Note: Prior to 2020, most installations were at stores.



Self-Contained Hydrocarbon Commercial Cabinets Installed in Europe

(as of December 2022)



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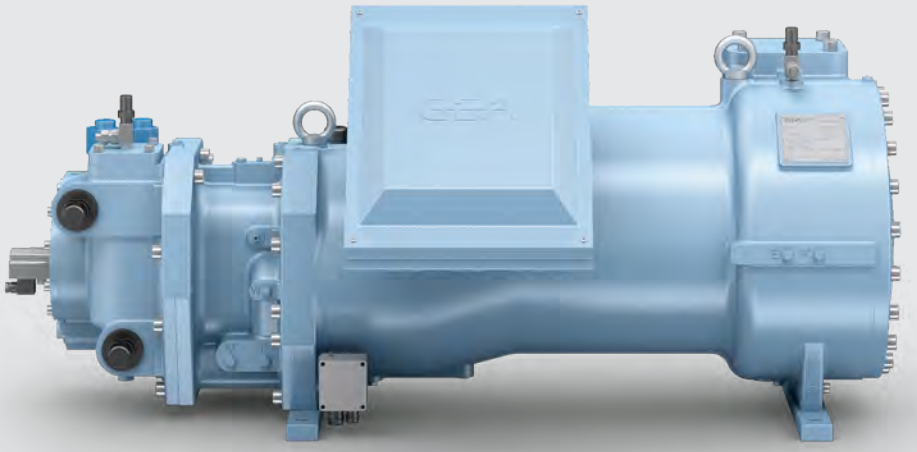
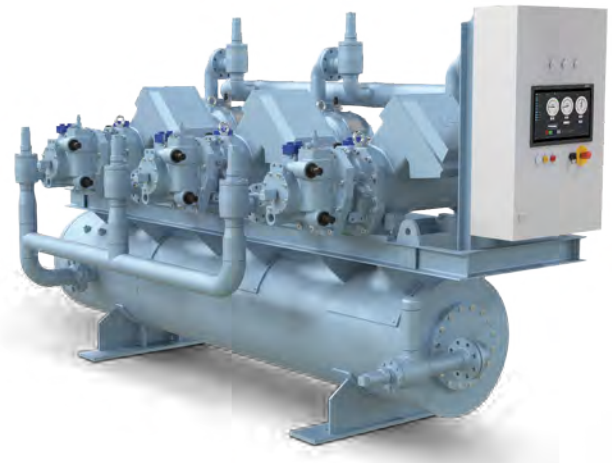
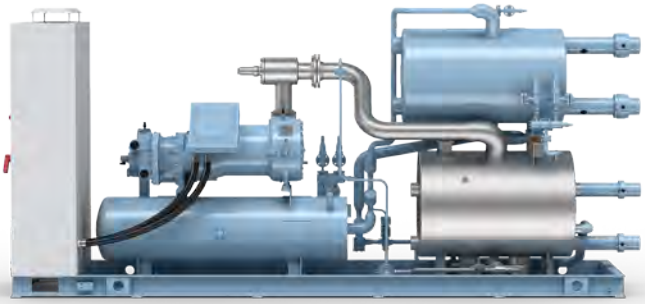


GEA Grasso CompaX 350/400



GEA Grasso X



GEA BluX

CHAPTER 9

European Market Data: Industrial Sites Using Natural Refrigerants

9.1 Transcritical CO_2

Background

Transcritical CO_2 made its first mark in Europe in the supermarket industry, with the first transcritical CO_2 multi-compressor system installed at a Bingo supermarket in Cornuda, Italy, in 2001.186

With the introduction of the EU F-gas Regulation in 2006, later updated in 2014, and in the process of another revision, Europe has become the world's leader in supermarket installations of transcritical CO_2. And in the past three years, larger transcritical CO_2 systems have gained traction in the European industrial refrigeration market as an alternative to ammonia and f-gas refrigerants in cold-storage, food processing and other facilities.

That transition has been helped by the development of industrial-sized compressors by manufacturers like Dorin. In 2018, Giovanni Dorin, marketing manager at the Italian company, correctly observed that transcritical CO_2 technology was poised to take off in industrial applications within the next three to five years.[187]

For example, in June 2019, BrewDog, a Scottish multinational brewer, commissioned a transcritical CO_2 refrigeration system from Star Refrigeration at its Eurocentral cold-storage facility in Scotland.[188]

The Market Today

ATMOsphere's June 2020 data collection from OEMs found 1,450 industrial sites in Europe using transcritical CO_2 (5% of the 29,000 CO_2 installations counted in Europe at the time).

Based on interviews with key OEMs, the majority of these installations were for the cold storage application.

As of March 2021, this number of industrial transcritical CO_2 installations in Europe was estimated to be 1,640 (4% of the 40,000 transcritical CO_2 sites).

Based on our 2022 survey of key OEMs, the number of industrial sites with transcritical CO_2 in Europe. as of December 2022, was 2,000 (3.5% of the 57,000 transcritical CO_2 sites).

9.2 Low-Charge Ammonia

Background

Ammonia was first used as a refrigerant in the 1850s in France. By the early 1900s, the basic design of the vapor compressor refrigeration system, using ammonia as a refrigerant, was established and has served since then as the backbone of the industrial refrigeration industry.[189]

But given its potential toxicity, efforts have been made over the past two decades to reduce the amount of ammonia used. The first concrete prototypes of systems with low and ultra-low charges were realized in the late 1990s, typically as a result of niche-level experiments performed at universities and R&D laboratories.

In 2001, Nestlé, which began using ammonia in place of CFC and HCFC systems in the 1980s, opened the world's first large NH3/CO_2 cascade system to use compressed CO_2, in Hayes, U.K.[190]

Beginning in 2015, modern low-charge systems began to be installed in Europe with the first installation of low-overfeed penthouse package systems. The following year saw the first installation of a low-charge central system.[175]

Since then, companies like Star Refrigeration, GEA, Mayekawa, Zudek and TEKO have been marketing low-charge units of various kinds and dimensions throughout Europe.

The Market Today

The Global Cold Chain Alliance (GCCA), whose members are third-party cold-storage operators, captures refrigerant usage information from members through its European Productivity and Benchmarking Research (EPBR). The EPBR carried out in 2019 on the 2018 business year reported that 79% of the respondents use ammonia only as refrigerant while 8% use ammonia and others.

GCCA has noted an increase in low-charge ammonia systems among members but does not offer a breakdown of these systems as a portion of total ammonia systems. However, according to interviews with OEMs, it is estimated that around 80% of all low-charge ammonia installations currently in Europe are for cold-storage facilities.

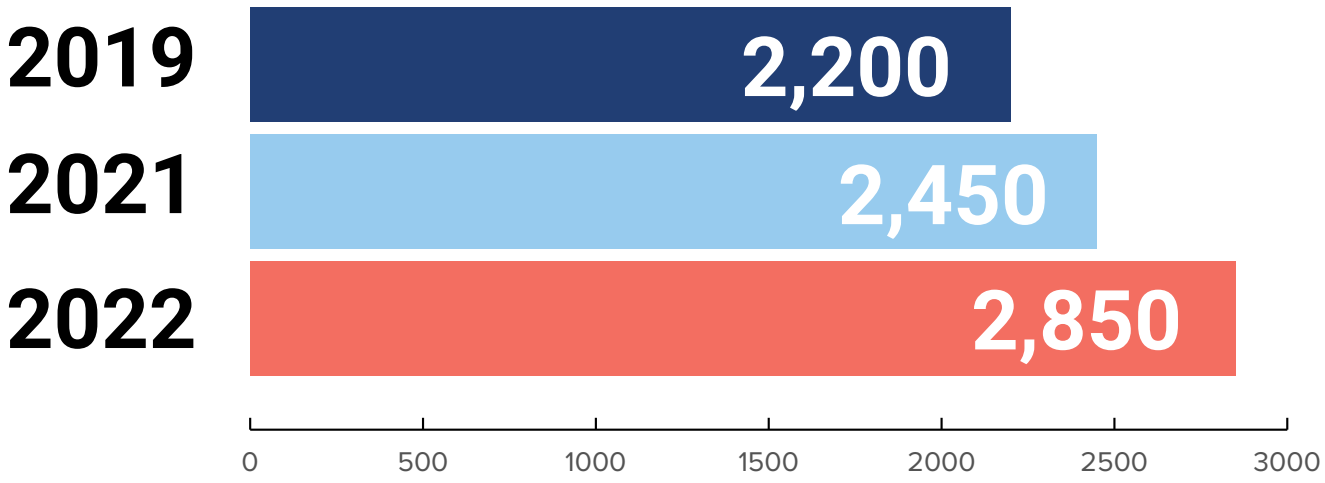
As of June 2019, ATMOsphere estimated the number of industrial sites of all types using low-charge (below 1.3kg/kW or 10.1lbs/TR) ammonia systems in Europe to be 2,200, according to data collected from OEMs.

Based on updated information and input from relevant experts, the number of industrial sites with low-charge ammonia in June 2021 in Europe was estimated to be 2,450.

In 2022, based on a survey of key OEMs, the number of industrial facilities with low-charge ammonia systems as of December was estimated to be 2,850.

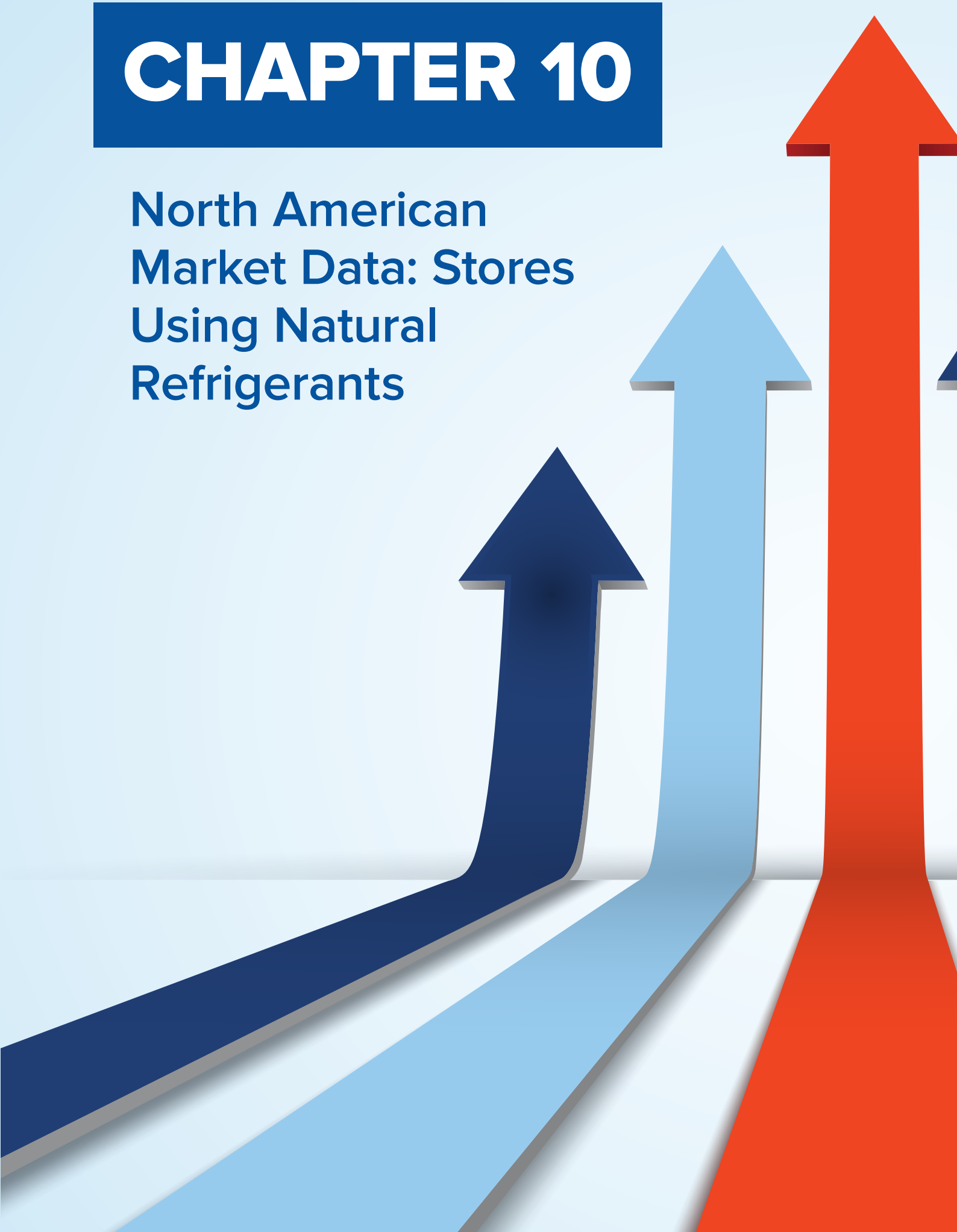
Growth of Low-Charge Ammonia in Europe

(industrial sites)



CHAPTER 10

North American Market Data: Stores Using Natural Refrigerants



10.1 Total Addressable Market

In 2021, there were an estimated 193,180 food retail stores in operation in the U.S., including 40,460 supermarket and grocery store businesses and 152,720 convenience stores.

Operators of supermarkets and grocery stores offer general lines of food products, including fresh and prepared meats, poultry and seafood; canned and frozen foods; fresh fruits and vegetables and various dairy products. Delicatessens are also included. A convenience store is defined as "a small retail business that stocks a range of everyday items such as snack foods, soft drinks, groceries, confectionery, tobacco products, over-the-counter drugs, toiletries, newspapers and magazines."

In 2022, there were 63,348 supermarkets and grocery stores[191] and 148,026 convenience stores[192] in the U.S. In Canada, there were 8,000 supermarkets and grocery stores[193] and 10,078 convenience stores.[194] In total in North America, there were 71,348 supermarkets and grocery stores and 158,104 convenience stores, for a grand total of 229,452 retail food stores.

10.2 Transcritical CO_2

Background

Given Europe's lead in the field of natural refrigerant systems, it's no surprise that a transplanted European – Predrag "Pega" Hrnjak, former research professor at the University of Illinois at Urbana-Champaign who died in 2022 – laid the foundation for the technology in North America. Inspired by Norwegian CO_2 visionary Gustav Lorentzen, whom he met in the early 1980s, Hrnjak and his team wrote research papers on virtually every aspect of CO_2 technology, as well as R290 and ammonia (R717) systems.

But it was not until 2006 that a U.S. retailer, Food Lion (part of European retail giant Ahold Delhaize) began testing CO_2 as a secondary refrigerant in low-temperature applications at a store in Montpelier, Virginia. Over the next few years, the chain added another secondary CO_2 test store and three stores that employed CO_2 in cascade (subcritical) systems with a primary HFC refrigerant.

In Canada, the Sobeys chain decided in 2008 to install a transcritical CO_2 system supplied by start-up Carnot Refrigeration (now part of M&M Carnot). However, it took longer for transcritical CO_2 refrigeration to reach the U.S. Finally, in July 2013, Hannaford, a Scarborough, Maine-based chain (also owned by Ahold-Delhaize), became the first U.S. supermarket to use the technology at a new store in Turner, Maine. Its supplier: Carnot, whose factory is 240 miles away over the border in Canada.

In December 2013, Whole Foods Market opened the second U.S. store to use a transcritical CO_2 system (from U.S. OEM Hillphoenix) in Brooklyn, New York. This store had the additional distinction of being the first in the nation to be completely HFC-free, from the HVAC systems and break-room refrigerators to the juice and beer dispensers.

Since then, Whole Foods has continued to install transcritical CO_2 systems in the U.S., and has also experimented with CO_2 cascade systems, which it began installing in 2009 (along with secondary CO_2 systems). In 2015, the chain opened a store in Dublin, California, which uses an ammonia/CO_2 cascade system – one of only five stores in the U.S. with this technology. The next year, Whole Foods opened the first, and so far only, U.S. store to employ a propane/CO_2 cascade system in Santa Clara, California. Because of regulation, California is the most active state for natural refrigeration installations.

The grocery chain that has become by far the leading user of transcritical CO_2 systems in the U.S. is ALDI US, which operates more than 2,000 stores across 37 states. The chain, an independently operated member of the German retailer ALDI Süd (South), announced last May that nearly 500 of its stores use CO_2 as the primary refrigerant,[195] an increase of almost 100 stores per year over the previous four years.

With the changing regulatory climate, other big retailers in the U.S. that were previously reluctant to consider transcritical CO_2 systems are now starting to deploy them. For example, last year, at a retrofitted Vista, California, outlet that it is calling its "first net zero energy store," U.S. retailer Target said that it has switched to CO_2 refrigeration, which the company will scale chain-wide by 2040 to reduce its direct operations' emissions by 20%.[196] The chain is known to have installed transcritical CO_2 in a number of other stores last year. In Canada, Sobeys uses transcritical CO_2 refrigeration in many stores (more than 100), as do other major Canadian chains like Loblaw and Metro.

Supermarket are the dominant retail users of transcritical CO_2 systems in North America. However, Hillphoenix, the leading producer of CO_2 systems for supermarkets, announced last year its first installation of a transcritical CO_2 system at a convenience store.[197]

In North America, CO_2 systems in stores typically use compressor racks, with one to 2.5 on average installed per store. While there is significant interest in CO_2 condensing units among supermarkets in North America, availability of this equipment remains relatively small to date. However, Hillphoenix introduced its first CO_2 condensing unit for store cabinets and cold rooms last year.[198]

Some observers see the supermarket industry approaching the "tipping point" for transcritical CO_2 refrigeration in the U.S. as food retailers are no longer just testing the technology, which they now see as proven in the marketplace. The only factor holding some operators back is the small price premium (5–10%) for transcritical CO_2, though that continues to shrink with greater production volumes. As they did in the Europe, transcritical CO_2 installations should begin to take off in the U.S. in the supermarket industry over the next few years.

The Market Today

As of December 2022, there were 1,895 sites (stores and industrial locations) with transcritical CO_2 refrigeration systems in North America (U.S. and Canada), including 1,150 sites in the U.S. and 745 sites in Canada.

In the U.S., there were 1,030 stores and 120 industrial sites using transcritical CO_2 systems, while in Canada there were 575 stores and 170 industrial sites equipped with this refrigeration technology.

In North America, commercial installations of transcritical CO_2 systems are almost exclusively at supermarkets and grocery stores. Of the 71,348 supermarkets and grocery stores in North America, the market penetration for transcritical CO_2 refrigeration is 2.2%. If convenience stores, a potential market for transcritical CO_2, are added, then the market penetration of the 229,452 total outlets in North America is 0.7%.

Since 2020, transcritical CO_2 installations in North American stores have grown from 945 to 1,605. In the U.S. CO_2 store installations have increased from 605 to 1,030 while in Canada they have jumped from 340 to 575.

Propane (R290)-based self-contained display cases, both air-cooled and water-cooled, will compete with transcritical CO_2 in complete-store installations in smaller stores, more so when charge-limit increases are approved in North America. Propane cases may also take up more center-store space in larger stores that primarily use a transcritical CO_2 system.

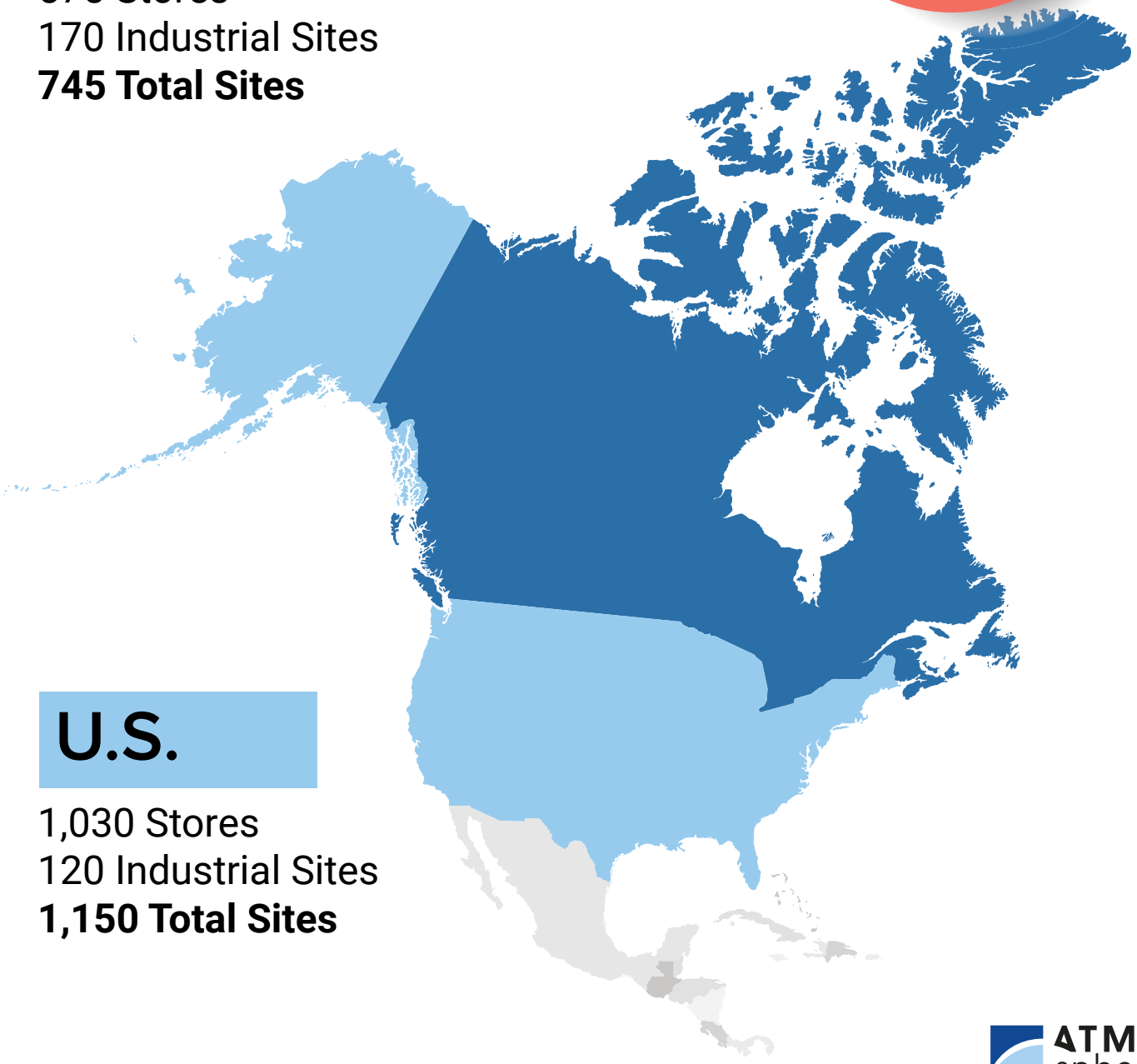
Transcritical CO_2 Installations in North America

(as of December 2022)

1,895
Sites with transcritical CO_2

Canada

575 Stores
170 Industrial Sites
745 Total Sites



U.S.

1,030 Stores
120 Industrial Sites
1,150 Total Sites

ATMO sphere

Transcritical CO_2 Commercial Refrigeration Market Penetration in North America

229,452 total stores*

0.7% transcritical CO_2 stores

71,348 supermarkets and grocery stores**

2.2% transcritical CO_2 stores

*IBISWorld and NACS
**IBISWorld

ATMO sphere

Transcritical CO_2 Installation Growth in North America

(stores)

2020	945
2022	1,605

U.S.

2020	605
2022	1,030

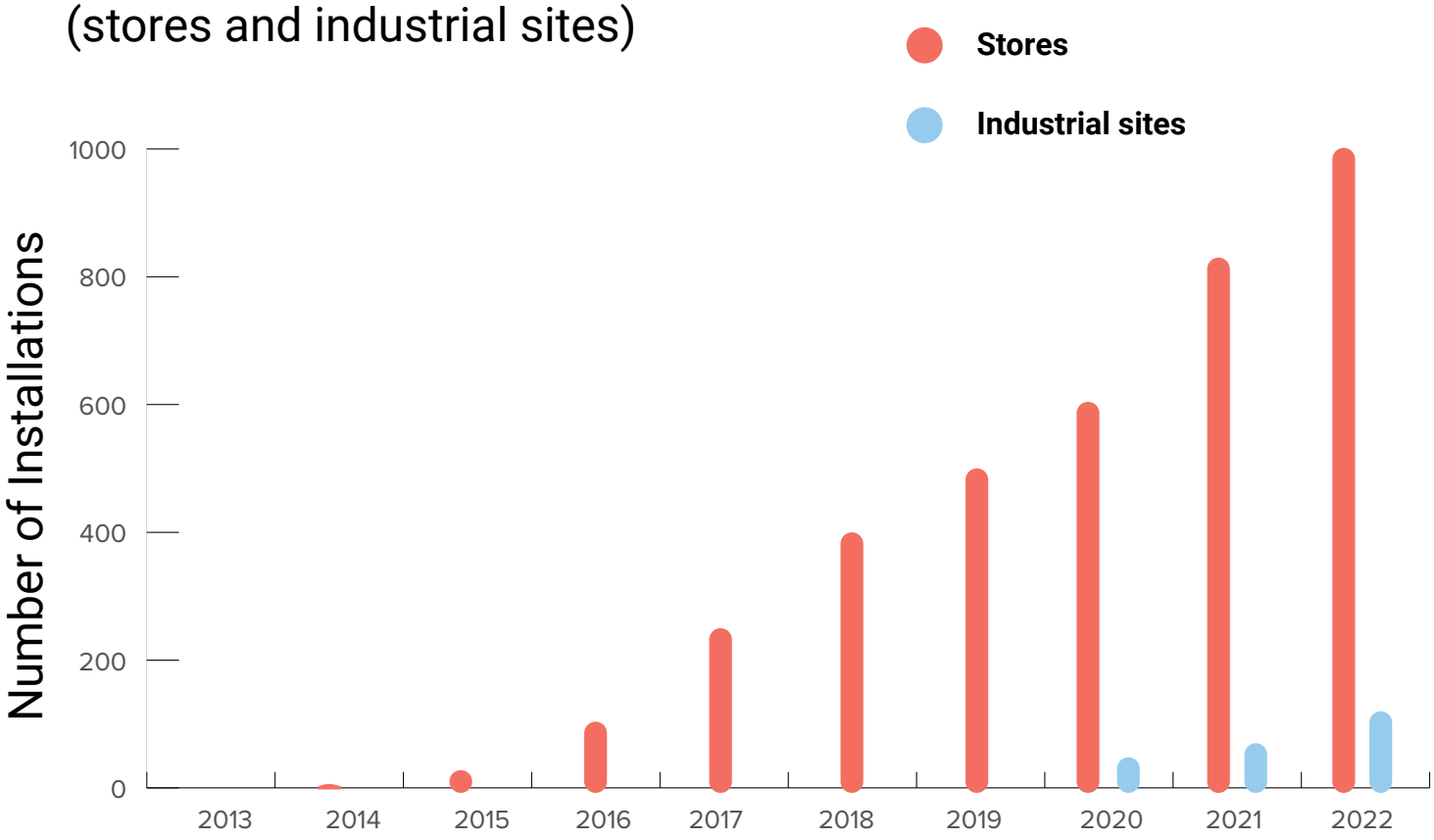
Canada

2020	340
2022	575

ATMO sphere

Transcritical CO_2 Installation Growth in U.S.

(stores and industrial sites)



Note: Prior to 2020, most installations were at stores.

ATMO sphere

10.3 Hydrocarbon Self-Contained Cases

Background

In addition to CO_2 in transcritical and cascade/secondary systems, the other natural refrigerant used by U.S. grocers in significant numbers is propane (R290), largely in self-contained display cases at the checkout or in spot merchandising locations (with a maximum charge of 150g).

In 2012, Unilever began delivering R290-based ice cream chest freezers to U.S. stores. The big uptick in R290 case adoption in the U.S. began in 2016, in anticipation of the more stringent energy standards released in March 2017 by the U.S. Department of Energy (DOE). The need for better energy efficiency boosted adoption of R290, a highly efficient refrigerant, and other technologies such as variable-speed compressors and more efficient fans. Since then, virtually all of the major commercial display case OEMs have transitioned to hydrocarbon refrigerants.

Today, just about every U.S. supermarket deploys at least some hydrocarbon-based beverage coolers at the checkout, and many use them as horizontal ice cream freezers and grab-and-go units at strategic locations. In addition, a small but growing number of stores are using R290 cases throughout the sales area. For example, as of 2021, about 150 stores had installed R290 cases from AHT throughout the store, and many other stores have deployed R290 cases from Hussmann in large sections or throughout the store. These stores are using semi-plug-in R290 cases attached to waterloop (glycol) systems that remove the heat of condensation.

Hannaford, a New England chain, has been testing R290 in complete frozen-food lineups in some new stores, with heat removed via waterloop. Last year, Hannaford reported that it had equipped the entire frozen section of its new store in Brunswick, Maine, with R290 self-contained cases supplied by Hussmann.[199] Hannaford took its inspiration from H.E. Butt Grocery, a Texas chain that in 2013 became the first U.S. grocer to install R290-based self-contained cases throughout a store.[200]

Another U.S. retailer exploring R290 lineups is ALDI US, which has installed solely R290 self-contained semi-plug-in display cases with a waterloop in at least two stores – including a California store that received state incentive funding – and only R290 air-cooled plug-in cases in at least one store.

Overall, hydrocarbon self-contained case installations in the U.S. represent a small percentage of the total installed cases in food retail, which are mostly remote cases. Remote cases are typically replaced by new remote cases in retrofits; the exception are horizontal chest "island" freezers that are harder to get to with piping.

Other opportunities exist for hydrocarbon cases in store expansions, club stores and small stores favoring plug-ins cases, as well as stores seeking a piecemeal approach to transitioning to natural refrigerants. In the future, some observers say, conventional U.S. supermarket chains interested in naturals may consider transcritical CO_2 for perimeter cases and R290 cases in the center store. On the other hand, CO_2 condensing units, for which there is growing interest in the U.S., could compete with self-contained R290 cases in smaller stores, and with HFO-blend condensing units in convenience stores.

In Canada, self-contained hydrocarbon cases have not been as widely adopted as in the U.S., according to multiple industry sources.

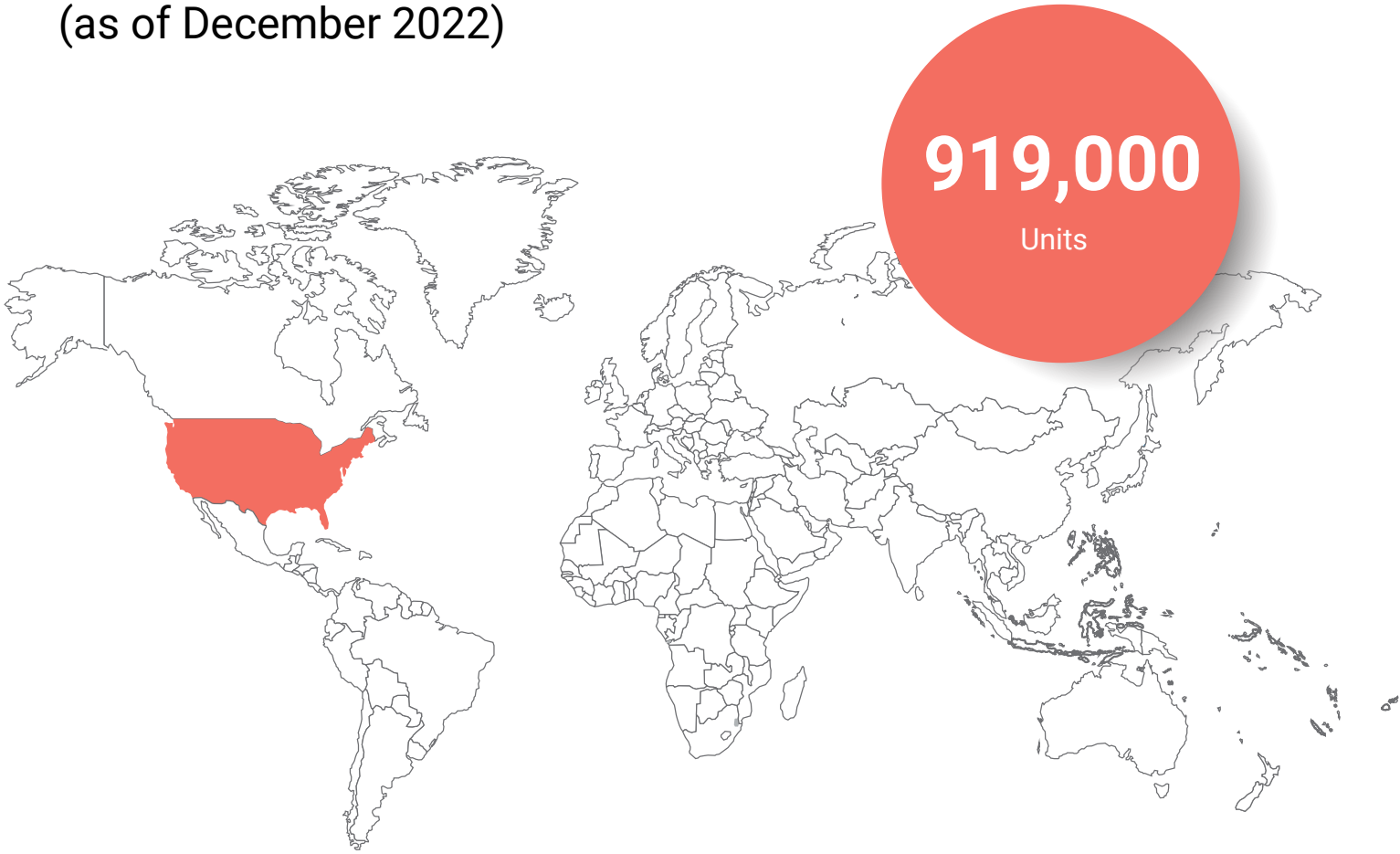
A sign that R290 cases may become more widely used throughout North America came in June of 2021 when Nidec Global Appliance announced it would be investing US$35 million (€30 million) at a production site in Mexico to build a new production line for its ES hydrocarbon compressors, increasing production capacity by 60%. The investment "will be focused on responding to the North American market demand, supporting the transition to natural refrigerants in this region."

The Market Today

As of December 2022, the number of self-contained hydrocarbon cabinets in U.S. stores was estimated to be 919,000. That's up from 875,000 units, including 500,000 beverage cases, in 2021.

Self-Contained Hydrocarbon Commercial Cabinets Installed in U.S.

(as of December 2022)



CHAPTER 11

North American Market Data: Industrial Sites Using Natural Refrigerants

11.1 Transcritical CO_2

Background

The U.S. was a little late to the game with transcritical CO_2 refrigeration, with the first supermarket, a Hannaford store in Maine, installing one in 2013. One of the first transcritical CO_2 industrial installations came five years later, when Henningsen Cold Storage (now owned by Lineage Logistics) installed one at its facility in Grandview, Washington.[201] Henningsen soon thereafter installed a second transcritical CO_2 system at a facility in Scranton, Pennsylvania.

Another early industrial user of transcritical CO_2 in the U.S was a Mama LaRosa Foods Italian-style dough plant in Taylor, Michigan. In 2019, Yosemite Meat processing plant in Stockton, California, installed one of the largest transcritical CO_2 plants in the world, with a total cooling capacity of 4MW (1,137TR).[202]

Over the past few years, industrial installations of transcritical CO_2 in the U.S. have become more widespread, supplied by such OEMs as Hillphoenix, M&M Carnot and Zero Zone. End users include cold storage, food processing, pharmaceutical, manufacturing and ice rinks.

In North America, ammonia has dominated the industrial sector for decades and is expected to continue to do so, particularly for large food processing facilities. However, in smaller food processing and cold storage operations, transcritical CO_2 has been making great progress as end users seek to avoid regulatory pressures that come with ammonia and HFCs. CO_2 is also a very inexpensive refrigerant (under US$2/lb) and has minimal leakage due to the use of stainless steel pipes.

At industrial sites, CO_2 systems primarily employ racks (one to 1.5 on average) but some are beginning to use condensing units (one to two per site). Last year, M&M Carnot installed 12 of its Aquilon DS industrial CO_2 condensing units, introduced in 2021.[203]

Overall, observers see transcritical CO_2 adoption continue exhibit strong growth in industrial refrigeration as contractors acquire more experience with it. Reflecting that, M&M Carnot is constructing a new facility in Maryland to build industrial CO_2 systems.

Another significant user of transcritical CO_2, falling outside the traditional industrial refrigeration sector, are data centers. Carnot Refrigeration (now part of M&M Carnot) has supplied more than 100 data centers with its Aquilon CO_2 cooling system.

The Market Today

In North America, as of December 2022, there were an estimated 290 industrial sites using transcritical CO_2 refrigeration (15.3% of the total), including 120 (10.4%) in the U.S. (up from 70 in 2021) and 170 (23%) in Canada.

11.2 Low-Charge Ammonia

Background

The basic design of the vapor compressor refrigeration system, using ammonia as a refrigerant, was established by the early 1900s and has served since then as the backbone of the U.S. industrial refrigeration industry.

Beginning in the 1980s, companies like Campbell Soup started implementing low-charge ammonia systems. In 2003, Nestlé built its first NH_3/CO_2 system using compressed CO_2 in the U.S. in a prepared foods factory in Jonesboro, Arkansas.[204]

Starting in 2010, Campbell's low-charge program focused on its Pepperidge Farm bakeries, where the company has converted R22 refrigeration systems to low-charge ammonia packages.[205]

However, the biggest push to install low-charge ammonia systems in the U.S. began in 2016 when Western Gateway, a cold storage operator in Utah, installed the first Evapco low-charge ammonia packaged unit on its roof.[206] Other producers of low-charge packaged systems also began offering systems, including NXTCOLD, Azane (a division of U.K.-based Star Refrigeration), Stellar and, more recently, Mayekawa,[207] Frick[208] and M&M Carnot.[209]

But another approach – implemented by Liberty Cold Storage in Illinois in 2018 – is to keep the stick-built, central-engine-room format traditionally used by industrial operators but employ a DX (direct expansion) evaporator from Colmac Coil Manufacturing for both medium-temperature and low-temperature applications.[210] Other companies such as Frick have also come out with centralized low-charge systems.[211]

Ammonia/CO_2 central systems, which confine ammonia to the engine room, are also considered low-charge systems. They began to be installed in the early 2000s, and now number well over 100 in North America, supplied by such manufacturers as M&M Carnot and Innovative Refrigeration Systems.

The Market Today

In North America, as of December 2022, there were an estimated 950 industrial sites with installations of low-charge ammonia systems, including 100 with packaged units and 850 with central (engine room) systems. There were 650 industrial sites (570 with central and 80 with packaged systems) in the U.S. and 300 (280 central and 20 packaged) in Canada.

In the U.S., there were 600 industrial sites with low-charge ammonia systems in 2021 and 525 in 2019.

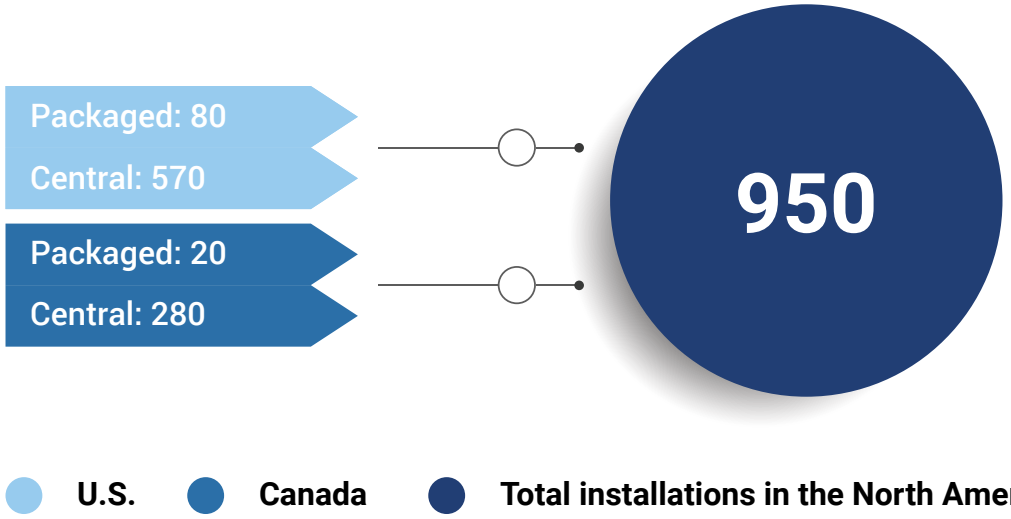
In 2021, according to Global Cold Chain Alliance (GCCA) data collected from cold storage members in North America, the refrigerant breakdown in cold storage applications was:

- 85% use ammonia only
- 4.5% use ammonia and fluorinated refrigerants
- 4.5% use fluorinated refrigerants only
- 4% use ammonia and CO_2
- 1.5% use CO_2 only
- 0.5% use CO_2 and fluorinated refrigerants

There has been a definite trend towards low-charge ammonia systems, minimizing some of the safety and regulatory concerns associated with large charges of ammonia.

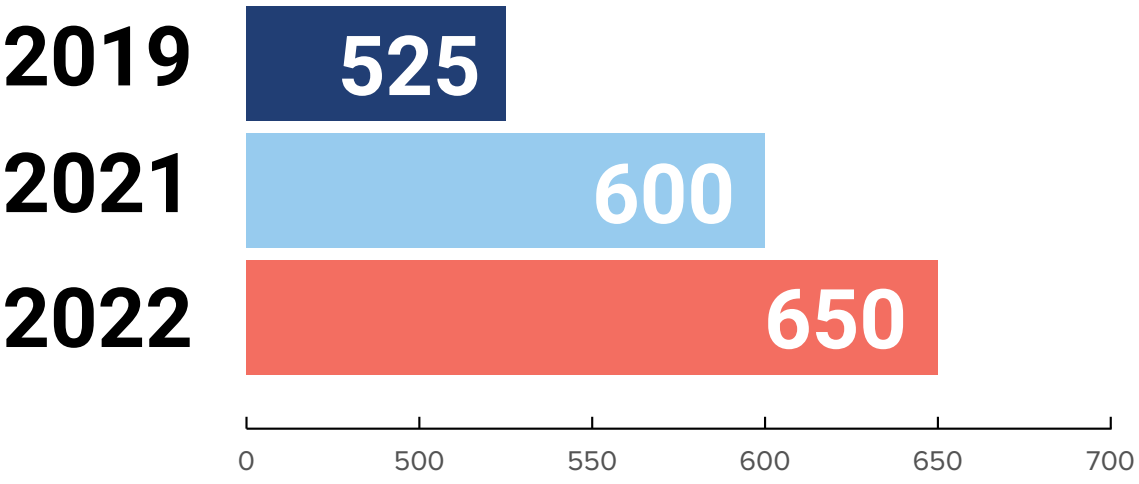
Installations of Low-Charge Ammonia Systems in North America

(industrial sites as of December 2022)



Growth of Low-Charge Ammonia Installations in U.S.

(industrial sites)



CHAPTER 12

Japanese Market Data: Stores and Industrial Sites Using Natural Refrigerants

12.1 Transcritical CO_2 at Stores

Total Addressable Market

There were an estimated 55,838 convenience stores in Japan by the end of December 2022.[212] At that time, there were an estimated 21,229 supermarkets in Japan.[213] Combined, this amounted to 77,067 food retail outlets in Japan.

The typical floor size for supermarkets in Japan measures around 1,381m^2 (14,865ft^2) on average. Typical temperatures are -18°C (-0.4°F) for frozen food, 0–10°C (32–50°F) for dairy, 0–4°C (32–39.2°F) for meat and fish and 5–10°C (41–50°F) for vegetables.

Background

While large scale transcritical CO_2 rack systems first started popping up in Europe's commercial refrigeration sector in the early 2000s, Japan began its natural refrigerant commercial refrigeration journey on the smaller end of the CO_2 scale.

The origins of natural refrigerant technologies used in Japan's commercial refrigeration sector can be traced back to the installation of the country's first transcritical CO_2 heat pump systems in the residential hot-water heating sector.

The first Eco Cute CO_2 hot water heat pump was introduced by Denso in Japan in 2001. It was the first CO_2 system to see widespread commercial success in Japan's residential and commercial hot-water markets. As of November 2022, there were an estimated 8,515,447 installed Eco Cute CO_2 hot water heat pumps in Japan's domestic hot water heating market.[214]

As CO_2 transcritical technology became proven in the residential heat pump market, similar technologies based on these systems were gradually scaled up in capacity to serve the cooling needs for the country's commercial refrigeration sector.

The majority of CO_2 transcritical systems in Japan's commercial refrigeration sector are now used in convenience stores, which employ air-cooled CO_2 outdoor condensing units (OCU) ranging from 2 to 20HP, rather than CO_2 rack systems. In 2010, major Japanese convenience store operator Lawson installed its first OCU. Within a few years, the number of installations grew into the thousands, making Lawson the world's leader in the adoption of transcritical CO_2 in commercial food retail.

The leading provider of OCUs in Japan is Panasonic, with 13,800 units for medium- and low-temperature applications installed at 4,500 stores in Japan as of March 2022.[215]

In supermarkets, the uptake of transcritical CO_2 OCUs still remains relatively limited, though a significant increase in adoption is expected over the next few years.

CO_2 technology is relatively mature compared to other natural refrigerants in the commercial refrigeration sector. Due to this technology maturity, the costs of manufacturing the systems are continuing to decrease, and widespread adoption and multiple reference projects and installations have made CO_2 an accepted solution for the food retail market in Japan.

However, the expected increasing market share of HFO blends like R448A for commercial food retail, due to Japan's relatively unambitious f-gas laws, is expected to act as a barrier to maximizing uptake of CO_2 in this sector. Some investments will also be made in hydrocarbon cases, but these are mostly complimentary island freezers.

The Market Today

As of December 2022, there were 6,630 stores (including 6,330 convenience stores) using transcritical CO_2 systems in Japan's commercial refrigeration sector, up from approximately 5,800 stores reported in 2021. The majority were installed by convenience store chain Lawson, which had 5,028 stores using CO_2 OCUs as of December 2022 (more than one-third of their fleet of 14,656 stores). 7-Eleven Japan is another significant convenience store user of transcritical CO_2, with 215 outlets employing the technology as of March 2021.[216] In the supermarket sector, there were an estimated 300 stores using transcritical CO_2 refrigeration as of December 2022.

Though uptake of transcritical CO_2 in supermarkets has been limited in Japan so far due to certain cultural and technological preferences, it is expected that this sector will be one of the top candidates for rapid growth of transcritical CO_2 system adoption in the next few years.

12.2 Transcritical CO_2 at Industrial Sites

Background

In just the past three to five years, Japan has seen a significant uptick in the adoption of CO_2 transcritical systems by end users in the cold storage and food processing industries as companies face increasing pressure to phase out the use of traditional refrigerants such as R22 and increase efficiency.

As in the commercial sector, the CO_2 technology used by the industrial sector is mostly outdoor condensing units (OCUs) up to 100HP. Hot climates have not been a deterrent to CO_2 installations as, for example, Yoshio Ice Manufacturing and Refrigeration, has installed CO_2 in an area that reaches 35°C (95°F) in the summer.

In 1988, Japan enacted the Act for Protection of the Ozone Layer, which imposed limits to production and consumption of R22 in Japan. A total ban on production and import of R22 went into force beginning in 2020.

In addition, Japan's subsidy scheme provided by the Ministry of the Environment has been a major driver of natural refrigerant systems in the industrial refrigeration sector.

In July 2017, the High Pressure Safety Institute of Japan (KHK) announced that CO_2 would be reclassified under Japan's High Pressure Gas Safety Act, meaning that several administrative requirements no longer applied to any manufacturer of CO_2 equipment with a daily refrigeration capacity under 20TR (70kW). This change opened the door for significantly wider adoption of larger CO_2 systems in Japanese industrial installations, where capacities are typically under 20TR (70kW).

Due to these factors, transcritical CO_2 systems are increasingly seen as climate-friendly and energy-efficient alternative solutions in the Japanese industrial market.

The Market Today

As of December 2022, there were an estimated 330 industrial sites (mostly cold storage) using transcritical CO_2 installations in Japan's industrial refrigeration sector, up from the 260 reported in 2021.

Major technology manufacturers such as Nihon Netsugen Systems (NNS), Mitsubishi Heavy Industries and Mayekawa have led this adoption trend in the past few years. For example, NNS has reported installing 410 transcritical CO_2 condensing units at 140 projects in Japan, with plans to more than double its production capacity in 2023 with the construction of a new factory to meet growing demand.[217]

As a result, there is increasing competition between transcritical CO_2 technology suppliers in the industrial refrigeration sector, as well as between CO_2 and ammonia/CO_2 secondary technology solutions. End-user case studies showing the costs and benefits compared to ammonia/CO_2 secondary technologies have made transcritical CO_2 increasingly competitive.

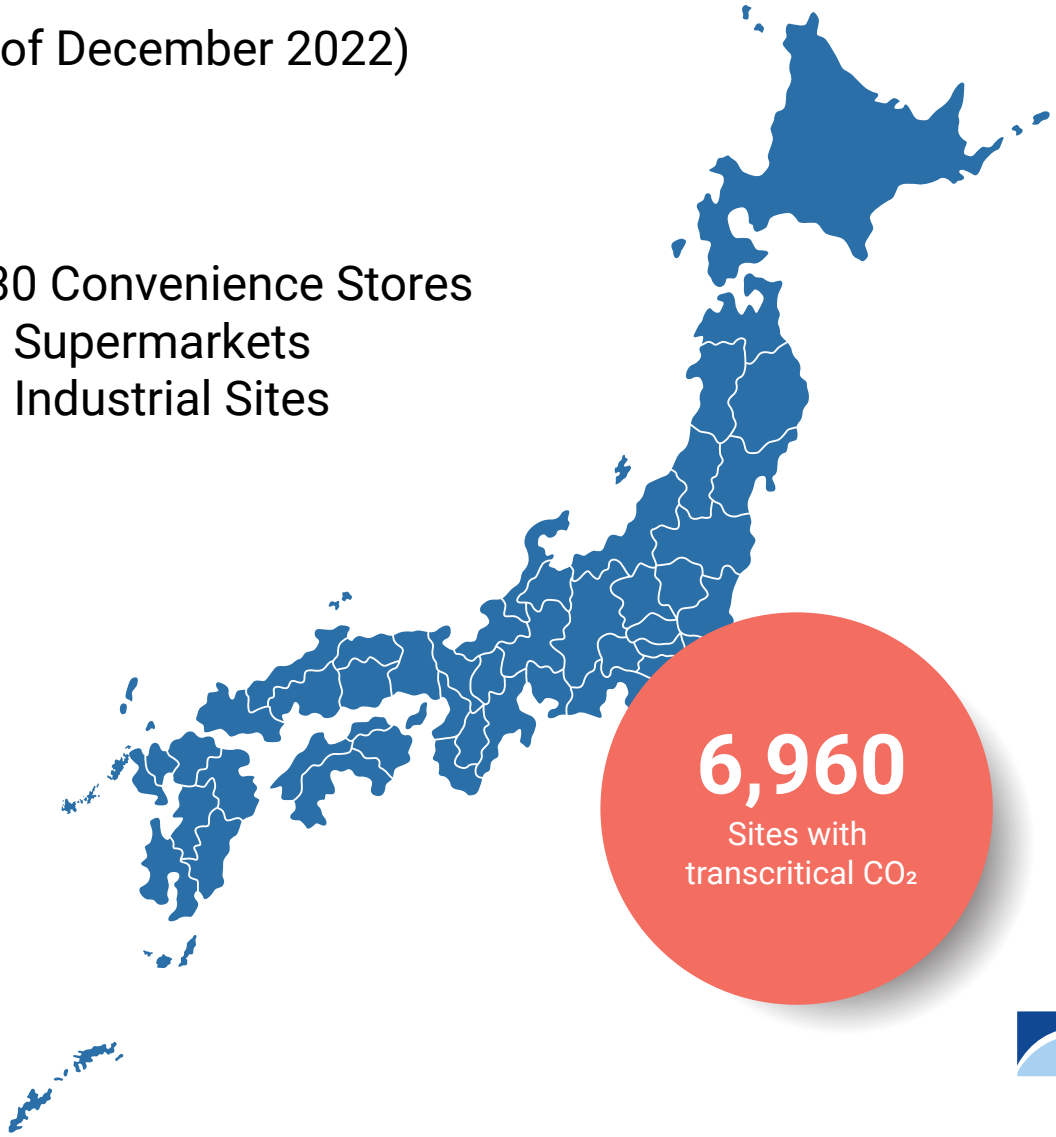
But NH_3/CO_2 systems still dominate the market share of natural refrigerant industrial installations, According to data from JARW members, cold storage facilities using CO_2 refrigeration account for only 4.2% of cold storage space, while those using NH_3/CO_2 (notably Mayekawa's NewTon ammonia/secondary CO_2 system and Mitsubishi Heavy Industries' system) represent 69.7%, and those employing liquid overfeed ammonia (a declining category) represent 25.6%.[98]

When it comes to installations of CO_2 systems in the industrial sector, cold-storage dominates with an estimated 90% market share, with the rest in food processing (tunnel freezing, beer brewing, margarine production, etc.). However, in the past few years, system installations, such as around four CO_2 tunnel freezer systems provided by Takahashi Manufacturing and Nihon Netsugen Systems, and end-user awareness have begun to point to signs of growth in the food processing sector, Meanwhile, suppliers such as Mayekawa and Mitsubishi Heavy Industries have supplied a number of NH_3/CO_2 systems in this sector as well.

Transcritical CO_2 Installations in Japan

(as of December 2022)

6,330 Convenience Stores
300 Supermarkets
330 Industrial Sites



ATMO sphere

Transcritical CO_2 Commercial Refrigeration Market Penetration in Japan

77,067 food retail stores

8.6% transcritical CO_2 stores (all)

55,838 convenience stores*

11.3% transcritical CO_2 convenience stores

21,229 supermarkets**

1.4% transcritical CO_2 supermarkets

*Japan Franchise Association
**Japan Supermarket Statistics Survey Office

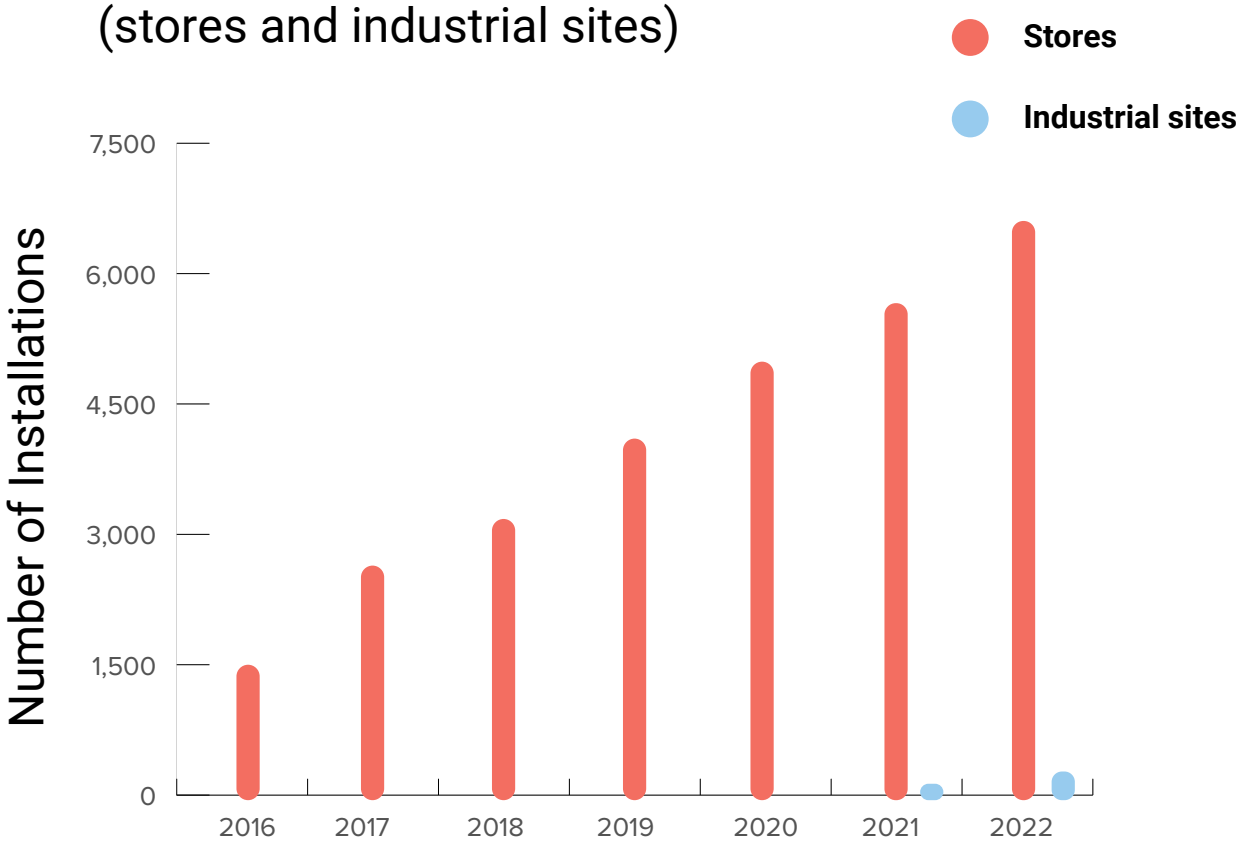
Transcritical CO_2 Installation Growth in Japan

(stores)

2021	5,800
2022	6,630

Transcritical CO_2 Installation Growth in Japan

(stores and industrial sites)



Note: Prior to 2020, most installations were at stores.

Charts

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