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GUIDE TO NATURAL REFRIGERANTS IN NORTH AMERICA

— STATE OF THE
INDUSTRY



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2015 GUIDE TO NATURAL REFRIGERANTS IN NORTH AMERICA

— STATE OF THE INDUSTRY

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Marc Chasserot

Publisher / Managing Director
of shecco

Welcome message by the Publisher

Shecco America is proud to present our newest publication, the GUIDE to Natural Refrigerants in North America – State of the Industry 2015, a follow up to our previous GUIDE to North America, published in 2013. During the last two years, we have been busy analyzing and quantifying the progress the North American market for natural refrigerants has made. In order to achieve this enormous task we have been attending key trade shows, as well as constantly being on the phone with the industry, collecting data and crunching numbers. This is not to mention launching Accelerate America, our own monthly magazine focusing on end-users and organizing huge annual events such as ATMOSphere America.

The result of all of this work is the publication you are reading now, which should provide a clear overview of the current market for natural refrigerants in North America, highlighting where both opportunities and potential problems lie for the industry as it continues to grow.

Whilst in absolute terms, progress in North America may not have accelerated as quickly as some would have hoped in the last two years, the overall signs for the market are still encouraging. Growth for natural refrigerant-based technologies in the light commercial and commercial refrigeration markets are in the triple digits while CO₂ continues to permeate North America's world-leading industrial refrigeration sector, where NH₃ has historically been the primary refrigerant of choice.

Widespread market growth has also coincided with the development of policies that are radically improving the business case for natural refrigerant-based solutions across all major sectors, in all major economies.

Most importantly, the North American market continues to usher in innovative CO₂, ammonia and hydrocarbons solutions in greater number. Amid the current state of re-orientation, this publication illustrates the considerable opportunities that exist for natural refrigerants in all major sectors – now, and in the future - as the market continues to mature and grow, as all signs indicate it will.

Happy reading.



Nina Masson

Lead Author / Deputy Managing Director
of shecco

Welcome message by the Lead Author

The North American market for natural refrigerants is one shecco has watched with keen interest since we published our first GUIDE to North America in 2013. We have seen first hand through our events that the market for natural refrigerants is growing, with new players entering every year with exciting solutions. However, it is difficult to quantify exactly how much progress has been made just from that.

Therefore, being able to devote our time to understanding the full extent of the use of natural refrigerants in North America has been a great experience and one full of surprises. We have seen that in many ways, North America is one of the global leaders in the use of natural refrigerants. For instance, we have large multinational companies with their headquarters in the United States driving change overseas in the light commercial refrigeration sector, securing a long-term future for hydrocarbons and CO₂. We were also pleasantly surprised to see that North America was not content with just being one of the biggest users of ammonia in the industrial refrigeration sector, but now utilizes many different solutions for the industrial sector such as CO₂ transcritical, CO₂/NH₃ cascade systems and low charge ammonia.

It was also exciting to see just how much the momentum coming from international and national regulatory measures and standards is steering the industry to natural refrigerants. But not just this, also that individual states and provinces are taking their own initiative to help eliminate fluorinated gases, with California and Québec being particular standout areas for the use and promotion of natural refrigerants.

While there are still areas which need improving, such as the use of natural refrigerants in the commercial refrigeration sector and the availability of training which is an affliction for the global HVAC&R industry, we can see that North America is now part of the driving force for natural refrigerants and I already cannot wait for what the market will look like this time next year, let alone in two or three.



Welcome message by Carnot Refrigeration

Carnot Refrigeration was founded in 2008 in Trois-Rivières, Québec, Canada. It was the very first company to provide CO₂ transcritical systems in the United States and received several awards for these projects, including the EPA Best of the Best award and GreenChill Platinum certification.

Our vision is to create and develop refrigeration systems throughout the world that are both respectful of the environment and economically advantageous in order to create a global standard for all sectors. Carnot provides long-lasting, customized, small carbon footprint and energy efficient equipment. Our CO₂ systems reduce greenhouse gas emissions and totally eliminate the use of HFCs. We strive to ensure that every client has the option of using natural refrigerants instead of substances that are harmful to the environment. It is for these reasons that Carnot Refrigeration is proud to support initiatives such as the GUIDE to Natural Refrigerants in North America, to promote natural refrigerants.



Marc-André Lesmerises, CEO
Carnot Refrigeration

Special supporter of the GUIDE North America 2015

**We create innovative,
customized and sustainable
refrigeration technologies.**

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–

High technology
Safe systems
Constant reliability
Incredible energy efficiency

WE SERVE

–

Data centers
Supermarkets
Food processing centers
Distribution centers

WE ARE

–

Carnot, leader
in the development of
CO₂ and NH₃ refrigeration
technologies



About this GUIDE

A short overview

To ensure a fruitful and efficient reading, what follows is a detailing of the separate chapters that make up the GUIDE to Natural Refrigerants in North America – State of the Industry 2015.



Chapter 1 – About this GUIDE – This chapter serves as a simple introduction to the world of natural refrigerants and what will be coming up later in the GUIDE.

First, the About the GUIDE section introduces the reader to the GUIDE survey, which collected the responses of hundreds of key stakeholders in the North American natural refrigerant market. This section will provide background information regarding those who were surveyed, including where they are based, application sector they work in and which role they currently hold. Following this, the stars of the GUIDE will be introduced, the “natural five” refrigerants: ammonia, carbon dioxide, hydrocarbons, water and air. This section will provide information about their chemical, physical, technical and environmental properties.

Chapter 2 – Application of natural refrigerants in North America TODAY – Through the use of independent research, survey and interviews, North America’s current natural refrigerants market is presented in a comprehensive and far-reaching evaluation. A clear focus is given to the key drivers that are emerging in North America in three different spheres: the market for natural refrigerants, the current policy climate and its technological development. The current state of the North American market for natural refrigerants is also conveyed in four “ecosystems”: City & buildings; Transport; Industry, special applications and sport; and the Food Chain. The

purpose of the “ecosystems” is to highlight the variety of natural refrigerant products and technologies currently in use in North America and the huge scope of adoption potential. In addition, an ecosystem containing samples of applications using natural refrigerants outside North America is provided to highlight areas of growth for the future.

Chapter 3 – Outlook for natural refrigerants in North America

TOMORROW - The future of North America's natural refrigerant market provides exclusive insights from the industry survey and from interviews with industry experts. This chapter helps build a blueprint of the industry's plan for provision and use of natural refrigerants in the future. The survey provides a clear indication of expectations regarding the future market, share in 2020 in different applications for natural refrigerants; and important factors that will drive the market.

Chapter 4 – Key applications for natural refrigerants in North America

– This chapter focuses on the three major applications for natural refrigerants in the North American market. These are: light commercial refrigeration, commercial refrigeration and industrial refrigeration. These three major applications show a dynamic development in terms of market uptake of natural refrigerants in the last few years and are expected to develop even faster in the coming years. Essentially, these are the applications to look out for.

Light commercial refrigeration – This section highlights the commitment of leading end users of global consumer brands to CO₂ and hydrocarbon-based solutions in North America's market. Through primary data collection, this section provides the current market size for CO₂ and hydrocarbon-based equipment in the United States, Canada and Mexico today.

Commercial refrigeration – CO₂ transcritical stores and cascade systems have grown impressively in the last two years and an installation map is included to show these changes in proliferation for both system types. The rest of the chapter goes on to explain why the market uptake has quickened, with increasingly conducive policies and technologies being developed to ensure transcritical solutions are available for all climates.

Industrial refrigeration – The last section highlights the exciting shift the market is taking as it goes from an ammonia-dominated sector to one which is becoming increasingly innovative with natural refrigerants in order to lower charge and increase efficiency. In this section, read about how CO₂, transcritical and low-charge ammonia are becoming the buzzwords of the future for industrial refrigeration.

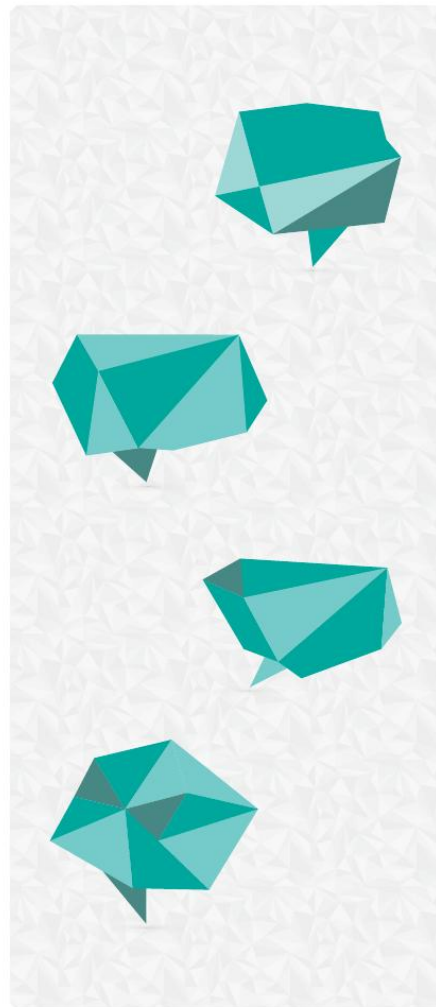
North American survey about natural refrigerants

Introduction

In order to provide an accurate current market share of natural refrigerants in North America as well as the future outlook for the use of natural refrigerant-based technology, shecco conducted an online survey among hundreds of experts in the North American HVAC&R sector.

The GUIDE survey asked the opinions of key stakeholders from the United States, Canada and Mexico on subjects such as the state of the market, the potential drivers and barriers for the uptake of natural refrigerant-based technology and the effectiveness of current relevant policy as well as the perceived effect of potential upcoming policy changes. These results add to the increasingly dense knowledge of the North American natural refrigerant market and work as an update to the previous GUIDE to Natural Refrigerants in North America published in 2013.

To further improve the accuracy of our findings, the GUIDE survey asks tailored questions depending on the respondent's area of activity, with the focus on light commercial, commercial and industrial refrigeration, which have shown the most dynamic developments for innovative natural refrigerant technologies in the last last two years. Those active, for example, in industrial refrigeration were asked their opinions on relevant policy for this sector, as well as key technological advancements. By including this division, the GUIDE is able to provide supplementary data to the key market, policy and technological trends for natural refrigerants in these key sectors.

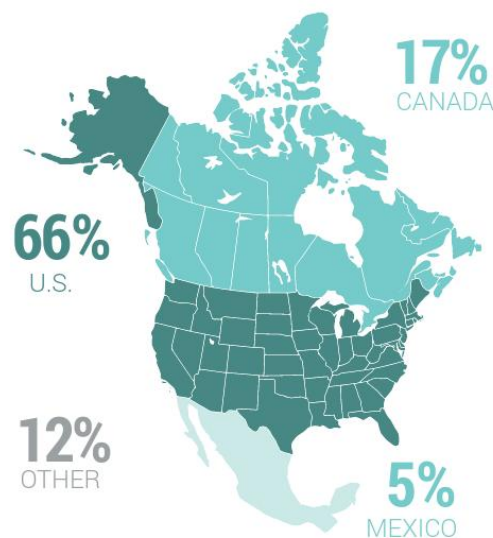


Detailed analysis of natural and non-natural refrigerant users

Within the survey itself, there was an incorporated distinction made between natural refrigerant users and non-natural refrigerant users to allow for the best understanding of the market and future developments. This dichotomy was created by analyzing the respondents' answers when they provided their current refrigerant usage status, with the subsequent questions in the survey being divided into two groups: organizations that are already using natural refrigerants and organizations that are not currently using natural refrigerants. Within this structure, we can easily grasp why organizations use and do not use, provide and do not provide natural refrigerant technology today, and their respective plans for the future. The survey also asks about current share and for future plans for natural refrigerants in the context of their entire R&D activities. Lastly, we identify the most important drivers for the market for natural refrigerants to grow in North America in the future.

Portrait of the North American industry

The results show that there is a great degree of diversity in the respondents' profile to the GUIDE survey to North America. The location of the organizations was particularly U.S. focused, which reflects the dominance that the U.S. economy and HVAC&R sector has over North America. 66% of the respondents indicated they were from the U.S., with 17% coming from Canada, 5% from Mexico and 12% noting they were from "other countries." The size of the companies shows that there is a big disparity as well, with both large and small firms being the dominant answers, with 40% of respondents noting they work for a "large" firm (over 500 employees) and 40% from a "small" firm (less than 99 employees), with just 20% from a "medium sized" firm (100 - 499 employees).



Number of respondents: 177

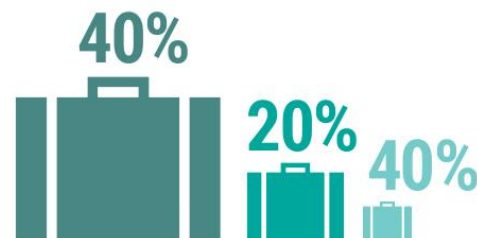
Size of U.S. HVAC&R sector shows in respondent profile

The United States was the predominant location of the GUIDE survey's respondents; with Canada having the second highest amount and Mexico last. This is a fair reflection of the size and scope of their respective HVAC&R markets.



In terms of the organization type that is represented, this was another mixed bag showing the clear range of respondents who answered the GUIDE survey, but on the whole there was a strong representation of the manufacturing sector. This representation can be seen by the fact that the most common respondent type was system manufacturers, which was chosen by 34.5% of respondents (who were allowed to choose more than one option). The joint second most popular choices were component supplier and engineering/contractor with 27% each, again demonstrating the strong practical basis of the respondents. Training/research was the fourth highest choice with 15.7%. There was also a high percentage of end users who answered the survey at 13.2%, showing that both supply and demand are being accounted for. Finally, consultancy/marketing and associations were the lowest represented in the GUIDE survey, with 10.7% and 3.8% respectively.

In terms of application representation, commercial refrigeration was the highest-represented sector with 72.3% of respondents noting that they worked in this sector (they again could choose more than one option). This strong showing for commercial refrigeration reflects the recent developments for natural refrigerant-based solutions in this sector. Industrial refrigeration was the second most common sector with 57.9% of respondents noting they worked in this sector. The industrial and commercial air conditioning sector was the third most common with 56% of survey respondents working in this field. Light commercial refrigeration followed this in terms of representation with 50.3% of respondents working in this area. Outside of this, the next significant market response is residential air conditioning and industrial and commercial heating, both accruing 38.4% of respondents' choices. Domestic refrigeration was next with 34% of respondents active in this application. The last options were 27.7% who are active in residential heating, 23.9% who are active in transport refrigeration and, 17.6% who were active in mobile air conditioning.



large organizations
medium organizations
small organizations



Size of companies shows an open industry

With a near-equal representation for large and small firms and a healthy size for medium-sized firms, it is clear that there are several organizations in different stages of development that answered the survey, with an interest from small innovative companies in natural refrigerant-based technology.





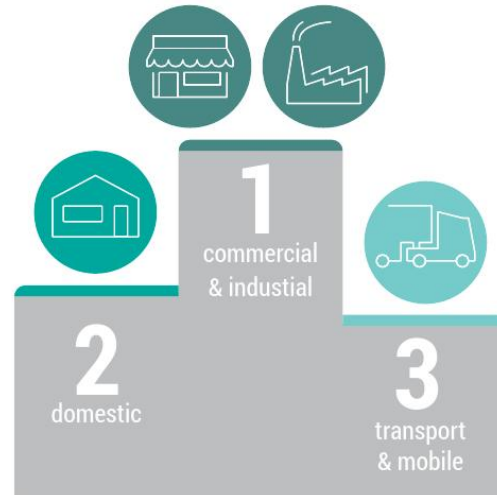
- System Manufacturer
- Engineering/Contractor
- Component Supplier
- Training/Research
- End User
- Consultancy/Marketing
- Association

Big industry turnout

The most-well represented groups are those who exert most influence; with system manufacturers and component suppliers along with engineers/contractors being the three most represented groups.



in heating, refrigeration & air conditioning applications



most represented area of activity

least represented area of activity

Commercial and industrial applications prevail

In terms of respondents, there is a clear leaning towards industrial and commercial applications in refrigeration, air conditioning and heating, as in all three sectors, these are the two highest-represented application sizes.



About natural refrigerants

As a general differentiation, “natural refrigerants” are substances that exist naturally in the environment, while “non-natural refrigerants” or “synthetic refrigerants” are man-made chemicals. The most commonly used natural refrigerants today are ammonia (NH_3 , R717) carbon dioxide (CO_2 , R744), and hydrocarbons (HCs), such as propane (R290), isobutane (R600a) and propylene, also known as propene (R1270).

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

The most commonly used natural refrigerants today are ammonia (NH_3 , R717), carbon dioxide (CO_2 , R744) and hydrocarbons (HCs), such as propane (R290), isobutane (R600a) and propylene, also known as propene (R1270).

Mixtures of ammonia and dimethyl ether (R723) have been developed, as well as various hydrocarbon blends with optimized performance and safety properties (isobutane/propane, R441 etc.). Water as a refrigerant has been used especially in absorption and adsorption chillers. The use of air is less common, but has been developed for deep-freezing applications.

With their wide availability, non-toxicity, non-flammability and unbeatable environmental credentials, water and air have shifted into the focus of R&D activities. Natural refrigerants no longer in use are sulphur dioxide (SO_2) and methyl chloride (CH_3Cl).



Carbon dioxide (ODP= 0; GWP= 1)

Carbon dioxide (chemical symbol CO_2 , refrigerant designation R744) is colorless, odorless and heavier than air. With a Global Warming Potential (GWP) = 1, CO_2 is the reference value for comparing a refrigerant's direct impact on global warming.

Carbon dioxide carries an A1 safety classification (the same as most fluorocarbon refrigerants), indicating that it has low toxicity and is non-flammable. CO_2 as a refrigerant is sourced as a by-product from a number of production methods. Although it is nontoxic, if enough carbon dioxide builds up in an enclosed space, it will begin to displace oxygen. Over a certain period of time, this can cause asphyxiation of those present. With a long atmospheric lifetime, CO_2 does not lead to any byproduct formation or decay products with serious environmental impact.

When used as a refrigerant, carbon dioxide typically operates at a higher pressure than fluorocarbons and other refrigerants. While this presents some design challenges, they can be overcome in systems designed specifically to use carbon dioxide. Carbon dioxide is compatible with some, but not all, commonly used refrigeration system lubricants. In particular, it is not suited for use with polyol ester (POE) and poly vinyl ether (PVE) lubricants and it only has limited applications with poly alkaline glycol (PAG) lubricants. It is generally regarded as a cheap and easily available refrigerant.



Ammonia (ODP= 0; GWP= 0)

Ammonia (chemical symbol NH_3 , refrigerant designation R717) is a colorless gas at atmospheric pressure. With zero ozone depletion and global warming potential, as well as a short atmospheric lifetime, it does not form any by-products or decomposition products with negative environmental impact. It is compatible with some, but not all, commonly used refrigeration system lubricants. In particular, it is not suited for use with polyol ester (POE) and poly vinyl ether (PVE) lubricants, and it only has limited applications with poly alkylene glycol (PAG) lubricants.

Despite its undisputed energy efficiency benefits, the use of ammonia is restricted in certain applications and geographic regions, due to its toxicity. As a result, R717 is effectively prohibited from use inside occupied spaces but can be used in unoccupied areas or outside.

However, many advances have been made in recent years to minimize risks for human health, particularly for ammonia installations in populated areas. These advances include using ammonia in conjunction with other refrigerants, such as in secondary systems, in order to reduce and isolate an ammonia charge, using advanced safety equipment, deploying containment casings, or using ammonia absorption systems.

It is important to note that ammonia has a strong odor, making leaks easy to detect.



Hydrocarbons (ODP= 0; GWP< 4)

With zero ozone depleting-characteristics and an ultra-low global warming impact, hydrocarbons (HCs) do not form any by-products or decomposition products in the atmosphere.

HC refrigerants can be applied either in systems designed specifically for their use, or as replacements in a system designed for a fluorocarbon refrigerant. This makes them a cost-competitive solution, and optimal for developing countries. If a hydrocarbon refrigerant is to be used in a system designed for a different refrigerant, it should be noted that modifications are probably required to ensure compatibility. Lubricant compatibility and the issues associated with hydrocarbons' flammability have to be addressed. However, the greatest potential for hydrocarbon refrigerants lies in new systems.

Hydrocarbon refrigerants are flammable and, as a result, carry an A3 safety classification, which means they have a low toxicity but are in the higher range of flammability. HCs are often subject to stricter safety requirements concerning the quantities permitted in occupied spaces.

Hydrocarbon refrigerants are fully compatible with almost all lubricants commonly used in refrigeration and air conditioning systems. One major exception to this rule is lubricants containing silicone and silicate (additives which are commonly used as antifoaming agents).



Water (ODP= 0; GWP= 0)

Water (chemical symbol H_2O , refrigerant designation R718) is one of the oldest refrigerants used for refrigeration applications. Also known as dihydrogen monoxide, water or water vapor is one of the earth's most abundant elements. Water has been extensively used as a process fluid (distillation, drying processes), as a heat transfer or energy storage medium (central heating, system cooling, ice storage systems) and as a working fluid in the Rankine power generation cycle. R718 is an environmentally safe refrigerant with zero ozone depletion potential and zero global warming potential. It is odorless, colorless, nontoxic, non-flammable, non-explosive, easily available, and it is one of the cheapest refrigerants.

In refrigeration applications, water requires state-of-the-art technology. Its use as a refrigerant has been mostly limited to compression chillers with steam injection compressors, absorption systems built around a binary fluid comprised of lithium bromide as the absorbent, and adsorption systems using water as the refrigerant and the mineral zeolite as the adsorbent.

From an environmental and thermodynamic point of view, water is an ideal refrigerant for applications above $0^{\circ}C$. R718 has a higher latent heat of evaporation ($2,270 kJ/kg$) than other natural refrigerants. R718 absorbs significantly larger amounts of energy, in the form of heat, during a change of phase, from liquid to gas, without a change in temperature. An obvious limitation is the high freezing rate at atmospheric pressure. Water leads to corrosion and oxidation of many metals. Water is more reactive than other refrigerants and choosing the right materials or the R718 system during the design phase requires special attention.



Air (ODP= 0; GWP= 0)

Air (refrigerant designation R729) is a refrigerant that is environmentally benign, cheap, totally safe and nontoxic. Environmental concerns about ozone depletion, global warming, and increasingly stringent legislation have renewed the interest in alternative refrigeration technology, globally. However, the use of air-cycle refrigeration systems is not new. It was used on refrigerated cargo ships around the turn of the 20th century.

Air cycle refrigeration works on the reverse Brayton or Joule cycle. Air as a refrigerant does not undergo phase change (condensation/evaporation) at the temperature levels encountered in conventional refrigeration applications. The COP value of air is low because of its lightweight, but air-cycle cooling systems can provide relatively high temperature heat recovery without the efficiency setback experienced by vapor compression systems. Air cycle units, compared to vapor-compression units, can also produce a much higher temperature difference between the hot and cold sides. As a result, very cold air can be produced for near cryogenic processes. The performance of an air cycle unit does not deteriorate as much as that of a vapor-compression unit, when operating away from its design point.

When operating in a refrigeration cycle, an air cycle unit can also produce heat at a useful temperature. Air has been used commercially for aircraft cooling for a long time. In spite of the low COP, air is used because of the specific operating conditions of aircraft (e.g., availability of compressed air and ram effect) and stringent specifications (e.g., low weight, small size, absolute safety, zero toxicity, etc.). Air has also been used as a refrigerant for residential and automobile air conditioning and cooling. In some refrigeration plants, air is used in the quick freezing of food products.

Refrigerants	Ammonia	Carbon dioxide	Propane	Isobutane	Propylene	Water	Air
Refrigerants number	R717	R744	R290	R600a	R1270	R718	R729
Chemical formula	NH ₃	CO ₂	C ₃ H ₈	C ₄ H ₁₀	C ₃ H ₆	H ₂ O	-
GWP (100 years)	0	1	3.3	4	1.8	0	0
ODP	0	0	0	0	0	0	0
Normal boiling points (°C)	-33.3	-78	-42.1	-11.8	-48	100	-192.97
Critical temperature (°C)	132.4	31.4	96.7	134.7	91	373.9	-
Critical pressure (bar)	114.2	73.8	42.5	36.48	46.1	217.7	-
Safety group	B2	A1	A3	A3	A3	A1	-
Molecular weight (g/mol)	17.03	44.0	44.1	58.12	42.08	18	28.97



Application of natural refrigerants in North America TODAY:

market, technology and policy trends

Introduction

During the time that has elapsed since shecco's last GUIDE to Natural Refrigerants in North America, in 2013, the North American market has gone from strength to strength, being galvanized by both a domestic and international impetus. Markets that two years ago were taking tentative first steps towards natural refrigerants, such as light commercial and commercial refrigeration, are now in the midst of a boom period boosted by sustainability commitments from large consumer brands as well as strengthened policy measures that aim to reduce emissions of fluorinated gases. Whereas in industrial refrigeration, new technological advancements such as low-charge ammonia and CO₂ transcritical systems are propelling the already natural refrigerant-friendly market further forward, making it a global leader.

The strengthening of policy has come in various forms, including approvals of new substances and delistings of high GWP refrigerants by the U.S. Environmental Protection Agency's Significant New Alternatives Policy (SNAP) Program, increased stringency in energy efficiency by the U.S. Department of Energy, and the continuing global HCFC phaseout. These measures have dislodged the pride of place that fluorinated gases previously possessed and given market presence to natural refrigerants such as ammonia, carbon dioxide and hydrocarbons.

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Shrieve. A global enterprise delivering world class technology yet flexible enough to build special relationships and meet your specific requirements. We have Technology Centers in the United States and China with expertise around the world ready to work with you.

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- Next generation technologies with environmental and performance advancements tailored for a wide range of natural refrigerants:
 - CO₂
 - NH₃
 - HCs
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Overview of market trends

AN INDUSTRY IN FLUX

In 2013, when the first GUIDE to North America was published, North America was more than often placed in a distant third place behind Europe and Japan in terms of the variety of applications utilizing natural refrigerants. Since then, there has been progress in all areas for the promotion of natural refrigerants - with many new doors opening for new opportunities, as well as those doors that were already opened, widening. One of the most significant factors contributing to this has been the tightening of policy that has affected the United States, Canada and Mexico, with each key application area being subjected to paradigm shifts since 2013. Due to these policy changes, natural refrigerants have been given the opportunity to shine since 2013 and now they play a significant role in aligning North America with the rest of the world.

However, it has also been suggested that the demand for natural refrigerant-based equipment and services may be outstripping the current capacity of the market, meaning that many in the industry feel that certain aspects are failing to keep pace. For instance, the market lags behind in the availability of trained engineers in both commercial and industrial refrigeration, which could be curtailing the speed of development.

But even in the midst of limitations, since the last GUIDE, the list of positives has only expanded and the list of negatives attributed to natural refrigerants has diminished. An increased focus on safety has been mitigating concerns over flammability and toxicity, especially in the use of ammonia, which has been subject to increased scrutiny and fines from the EPA in order to reduce incidents and improve confidence.

The increased uptake in natural refrigerant-based systems is also lowering prices across all applications and there is hope of simplified solutions for both industrial and commercial applications, with packaged solutions becoming increasingly prevalent. Energy efficiency is also being increasingly linked with natural refrigerants, and solutions for warm-ambient climates, especially in commercial refrigeration, are being developed and tested extensively.

All of these positive impacts have meant that natural refrigerants in the three key applications –light commercial, commercial and industrial refrigeration– have all seen growth in the triple digits since 2013, with much untapped potential to be explored during the next five years if the market is able to assimilate itself quickly enough to absorb and process the extra demand.

3 key and current market trends

CO₂ IN COMMERCIAL REFRIGERATION CONTINUES TO RISE

The use of CO₂ has grown in North America's commercial refrigeration, especially in Canada where CO₂ transcritical is becoming a strong trend for the mainstream market. Sobeys, Canada's second largest food retailer with 1,778 stores (852 of them franchised) has 15-20 stores being opened annually that will use CO₂ transcritical systems on top of the 78 they already have in their fleet. Outside of Canada, the United States has also experienced impressive growth, currently

boasting 52 CO₂ transcritical stores, and new technologies are available to allow for the proliferation of transcritical solutions in the warmer South. The growth of cascade systems across the United States also shows that there is a large capacity for natural refrigerants and with the appropriate technology the use of CO₂ in commercial refrigeration will become a no-brainer.

HYDROCARBONS SURGE IN NORTH AMERICA

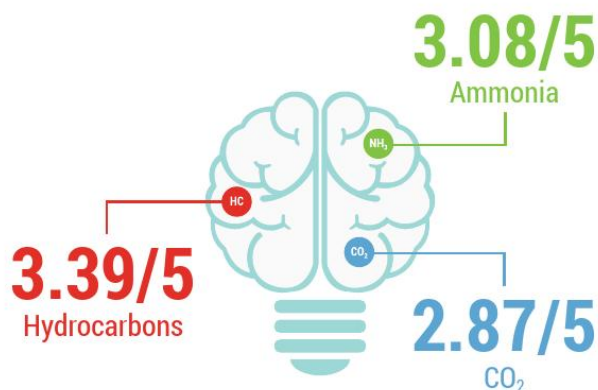
The use of hydrocarbons in light commercial applications is fast becoming a standard in Europe, and the future potential in China's future residential air conditioning market is impressive. Therefore, the North American trend for the adoption of hydrocarbons in light commercial applications follows a more general global trend. While the Coca-Cola Company is going ahead with a CO₂-only light refrigeration equipment policy, many other consumer brands are opting for hydro-

carbons and deploying hundreds of thousands of hydrocarbon freezers, coolers and cabinets across North America. This, combined with statements of intent to use hydrocarbons-based equipment from food service outlets such as McDonald's and Starbucks, further strengthens the future stock of hydrocarbons, which currently stands at 291,000 units in North America.

NORTH AMERICA STILL A WORLD LEADER IN USE OF NATURAL REFRIGERANTS IN INDUSTRIAL APPLICATIONS

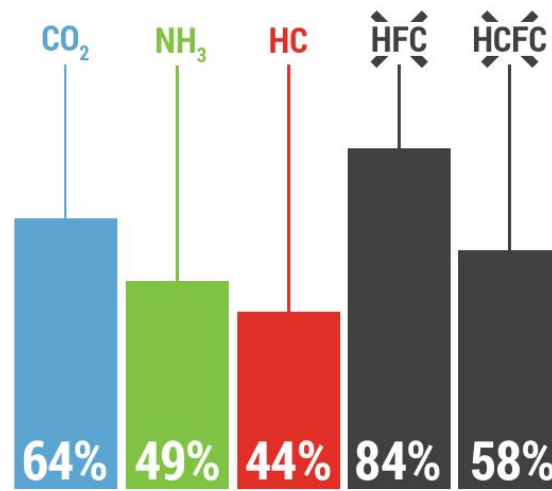
Industrial refrigeration was where North America already had an established market for natural refrigerants, and this trend has continued since 2013, with the total square footage of North America's cold storage amounting to 2.81 billion, over half of the world total of 4.73 billion cubic feet. In 2013, it was clear that ammonia was set to flow through the pipes of new installations as the banning

of R22 would make it expensive and short-lived to do otherwise; however, what was not so anticipated was the role carbon dioxide would have in this market. It is only fitting that while other sectors begin their journey to adoption of natural refrigerants, that the one already well endowed with ammonia evolves to explore the positive properties of other natural refrigerants.



Hydrocarbons lead the NR group in terms of industry familiarity

The results show that currently hydrocarbons have the highest degree of familiarity among the industry survey respondents in the natural refrigerant group. The wide use of hydrocarbons in all three major economies ensures it has the highest familiarity. CO₂ as a refrigerant is not as widely used in southern regions as it is in northern regions, which could explain the low ranking of familiarity with CO₂.



CO₂ edges closer to widespread usage closing gap with HFCs

Carbon dioxide is currently being used by 64% of the survey respondents, a higher level than that of the outgoing HCFCs, and a percentage that will have an inverse relationship to HFCs, which also appear to be living on borrowed time. Ammonia is used by 49% of respondents and is ubiquitous in industrial refrigeration applications but little else, so this percentage does not reflect its concentration in this particular market. However, with technology shifting to lower ammonia charge systems, this percentage could creep up with potential usage in commercial refrigeration. Hydrocarbons, as well, are contained by charge limitations that presently confine it to residential and light commercial refrigeration applications. But what is notable is that the gap between fluorinated gases and natural refrigerants is shrinking.



#GoNatRefs





What are the drivers and barriers for natural refrigerants in North America?



Considerations about legislation, efficiency and environmental impact drive market

The impact that legislation and environmental responsibility have is considerable, with adherence to current (and future) legislation, environmental impact alongside efficiency & performance labeled as the three most important motives. As these parameters continue to be reinforced and strengthened, it is expected that they will propel the market forward. Other criteria, such as availability and supply will also be increased by the market uptake being aided by policy measures.



Cost considerations still rank high in minds of industry

Cost considerations remain at the forefront of reasons why companies do not adopt natural refrigerant-based technology in North America today. The other key factor is demand & competitive advantage as well as safety perceptions. However, the cost of not switching from HFC systems will begin to eradicate this “premium-price” feeling as the cost of components for HFC systems will increase as well as the cost of the refrigerant used in the system, while the inverse will become true of natural refrigerant-based systems. This message was echoed at ATMOsphere America 2015, where a live-polling of the audience saw a majority of 43% indicating that initial cost was the greatest barrier to the rollout of natural refrigerant-based technology, supporting this industry survey.

Overview of policy trends in North America

INTERNATIONAL LEVEL: NORTH AMERICAN COUNTRIES INCREASE PRESSURE TO PHASE DOWN HFCs GLOBALLY

In 2015, the U.S., Canada and Mexico, for the seventh consecutive time, submitted a proposal to phase down HFCs under the Montreal Protocol. So far the progress in the negotiation process has been blocked by a group of developing countries due to concerns over technical, legal and financial aspects of phasing down HFCs, especially in view of existing commitments to phase out HCFCs. Nevertheless, the North American countries remain strong proponents of the global action on HFCs and are building up pressure to build consensus. The U.S. administration has initiated bilateral agreements with major economies, such as India and China, regarding the support of international action on HFCs.

The U.S. and Canada were also the founding partners of the Climate and Clean Air Coalition (CCAC) in 2012. The CCAC seeks to complement the global action to reduce CO₂ emissions through instigating new actions and reinforcing existing frameworks in order to reduce short-lived climate pollutants, including HFCs. In order to speed up the international process towards limiting the use of high-GWP HFCs, action needs to be taken at national level.



U.S. EPA SNAP Program



HCFC Phaseout



Introduction of requirements for low-GWP refrigerants at State level, e.g. in California



DOE energy conservation standards



Voluntary industry commitments

Several policy measures working together to accelerate uptake of natural refrigerants

At ATMOsphere America 2015, participants assessed through live polling a variety of policy measures in the U.S. in terms of their impact on accelerating the introduction of natural refrigerants through live polling. The EPA SNAP Program and the HCFC phase out are deemed to have the highest impact on accelerating the uptake of natural refrigerants, while voluntary industry initiatives are not believed to have a strong impact throughout the industry. But the advancements by Refrigerants, Naturally! and other companies can not be ignored.

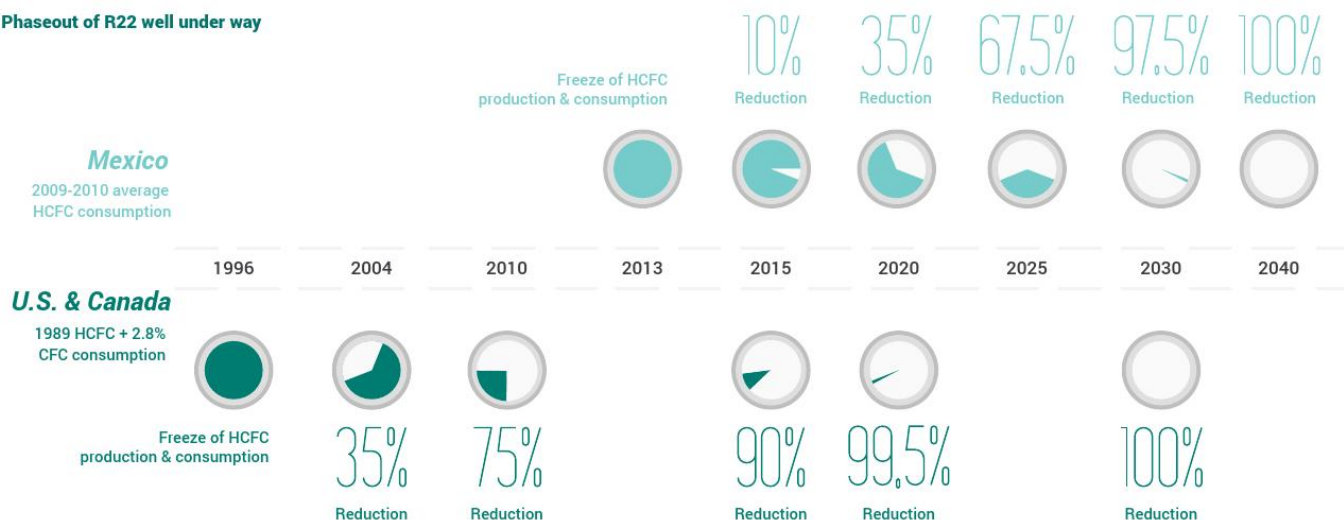
HCFC PHASE OUT PUSHES OUT R22, WELCOMES NATURALS

In accordance with the international agreement made in 2007 between the Parties to the Montreal Protocol, the North American countries are on their path to phase out production and consumption of HCFCs in a tapered fashion. Mexico, as part of the group of developing countries under the Montreal Protocol, has committed to phasing out 97.5% HCFCs by 2030 (compared to 2009-2010 levels), allowing 2.5% for servicing of existing equipment until 2040. The HCFC phaseout is helping Mexico to refocus its economy, with an increased role for hydrocarbons that is creating domestic suppliers who are manufacturing both hydrocarbons and CO₂-based equipment, leap-frogging the need for HFCs as they look to reduce their consumption of HCFCs.

The United States and Canada are following an accelerated HCFC reduction schedule, imposing restrictions on the use of R22 as of 2020. After 2020 the servicing of existing systems with R22 will rely on recycled or reclaimed refrigerants, until such practices become illegal as of 2030. With the decreasing supply of R22 over the next few years, prices are expected to rise, forcing end users to switch to more sustainable technologies.

In industrial refrigeration, the phaseout of R22 has helped states and provinces previously reliant on the refrigerant to switch to other refrigerants, with a high saturation of low-charge ammonia systems being placed in Quebec, a province previously associated with the use of R22 in industrial refrigeration.

Phaseout of R22 well under way



U.S. EPA SNAP PROGRAM MAKING AN IMPACT

The Significant New Alternatives Policy (SNAP) Program of the U.S. Environmental Protection Agency (EPA) evaluates and regulates substitutes for ozone-depleting chemicals (ODS). All substances that can potentially be used as refrigerants are, by default, not allowed on the market until deemed “acceptable,” either with or without use restrictions.

The SNAP Program has been one of the most significant legislative tools incentivizing the industry to invest in climate friendly technologies using natural refrigerants. Especially after 2013, when President Barack Obama announced his Climate Action Plan, making the phaseout of HFCs a national priority, the U.S. EPA has published a number of rules opening the doors to natural refrigerants in applications, where their use was not allowed before. One of the two most recent SNAP approvals listed CO₂ as acceptable for use in transport refrigeration. Another rule finalized in February 2015 approved a number of hydrocarbons for use in stand-alone commercial refrigeration, vending machines, residential and light commercial air conditioning and heat pumps. Such a legislative action has given a boost to hydrocarbons, especially in food service, with large consumer brands now being able to fully “naturalize” their equipment in North America, paving the way for other end users to adopt the technology.

Besides approving new substances in different end uses, the SNAP Program allows for withdrawal of previously approved refrigerants from the list (so-called “delisting”), making their use illegal in new or existing equipment. Delisting of high-GWP substances has an equally important bearing on the future of natural refrigerants in the U.S., and the following chapter provides further insight into a recent rule that forbids the use of certain high-GWP HFCs in a number of applications.

The significance of the EPA’s SNAP program has also been confirmed in a live polling at the 2015 ATMOSPHERE America event, where 57% of the audience of believed this legislative tool to be the most effective in driving natural refrigerants in the U.S.

List of natural refrigerants approved under U.S. EPA SNAP Program (status as of July 2015)

Application/type of equipment	CO ₂	HC	NH ₃
Domestic refrigeration	X	N* (R290, R600a, R441A)	X
Vending machines	N	N* (R290, R600a, R441A)	X
Retail food refrigeration	N	N* stand-alone equipment (R290, R600a, R441A)	N (ammonia vapor compression with secondary loop)
Commercial ice machines	X	X	N
Cold storage warehouses	N	X	N
Industrial process refrigeration	N, R	N, R* (R290, R600a, R1270)	N
Ice skating rinks	X	X	N
Refrigerated transport (cryogenic)	N	X	X
Refrigerated transport	N	X	X
Mobile AC	N*	X	X
Residential and light commercial AC and heat pumps	X	N* (R290, R441A)	X
Industrial process AC	X	X	N
Chillers	X	X	N
Very low temperature refrigeration	N, R	N* (Ethane)	X
Non-commercial heat transfer	N, R	N* (Ethane)	X

N = new systems

R = retrofits

X= not approved so far

* subject to use conditions

DOE STANDARDS INCREASING PREFERENCE FOR NATURALS

The EPA SNAP Program is not the only policy driving change in the U.S. as the Department of Energy's energy conservation standards also increase the preference for naturals in a variety of applications. The recent rulings, published in 2014, cover commercial refrigeration equipment, such as self-contained refrigerators, commercial freezers, display cases as well as ice makers and have a significant impact on the commercial refrigeration industry.

New DOE energy conservation standards will become effective as of 2017 for stand-alone refrigerated cabinets and 2018 for ice machines and already have the market gearing up for the switch to naturals, with many manufacturers previewing and introducing R290 equipment in anticipation of the stringent requirements.

UL STANDARDS ON HYDROCARBONS AND TRANSCRITICAL CO₂

Underwriters Laboratories (UL) is a North American independent product safety testing and certification organization. As new products, technologies and applications are consistently being introduced and old ones are updated, testing and certification requirements also evolve to keep up with the new demands, applications and safety implications. A Joint Task Group (JTG) was formed for the purpose of drafting requirements for large-scale refrigeration equipment using CO₂ as a refrigerant.

The key UL standards that presently include requirements applicable to equipment using CO₂ (transcritical and/or subcritical) include:

- » UL 207 - Refrigerant-containing components
- » UL 412 - Refrigeration unit coolers
- » UL 471 - Commercial refrigerators / freezers
- » UL 1995 - Heating and cooling equipment
- » UL 60335-2-34 - Refrigerant motor compressors

With regards to hydrocarbons, UL had established a Joint Task Group on flammable refrigerants in 2011, which issued its recommendations in September 2014. One of the outcomes is a recent revision of the UL 484 standard for room air conditioners to reduce the amount of flammable refrigerant allowed to 3 x LFL. The reviewed standard essentially restricts the charge size for propane in room AC to 114g, a limit that is far below what international safety standards have established. This creates concerns within the international community especially as R290 air conditioners with much higher charges have been successfully deployed in the hundreds of thousands with an excellent reliability and safety record.

UL is currently developing requirements for flammable refrigerants for heat pumps, air conditioners and dehumidifiers under UL 60335-2-40, which will make it possible for hydrocarbon-based products under this scope to be certified across North America once finalized. The limits proposed for flammable refrigerants are nevertheless more stringent than the international IEC requirements.

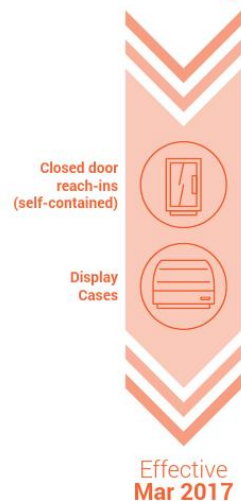
U.S. ADMINISTRATION TEAMS UP WITH PRIVATE SECTOR

In September 2014, ahead of the UN Climate Summit, the U.S. government partnered up with several private companies to announce a voluntary agreement for reducing HFC emissions. Coca-Cola, Red Bull, Target, and some of the manufacturers of natural refrigerant-based equipment are among those taking part in the initiative. The agreement is aimed at reducing the cumulative global consumption of fluorinated gases by 700 million tons of CO₂ by 2025.

In addition to actions driven by the private sector, the U.S. government will seek to promote the use of low-GWP refrigerants and encourage development of such technologies through a number of initiatives, such as:

- » *Enhancing public procurement of equipment using safe alternatives to HFCs:* In an Executive Order in March 2015, President Obama directed his administration to purchase products using low-GWP alternatives as identified by SNAP Program whenever feasible and transition over time to equipment that uses safer and more sustainable technology. In response to this, the U.S. Defense Department, NASA and the General Services Administration are proposing to change their regulations to insist on procurement of low-GWP refrigerants, which would require an amendment to the Federal Acquisition Regulation (FAR).
- » *Evaluating sustainable technologies in Federal buildings:* Technology manufacturers and industry stakeholders, including those that offer alternatives to HFCs, are invited to submit information on innovative and transformational building technologies that can be used in Federal buildings. Technologies will be evaluated within the Green Proving Ground program and results will be used to inform both the public and private sector, and enable them to make an informed decision and accelerate commercialization of the technology.
- » *Providing funding for R&D of technologies using alternative refrigerants:* The Department of Energy has announced new funding that will encourage development of energy efficient technologies that use alternative refrigerants to HFCs in heating, refrigeration, air conditioning and heat pump applications.

Energy level reduction
30%-50% kWh/ day



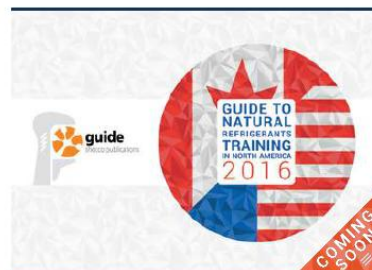
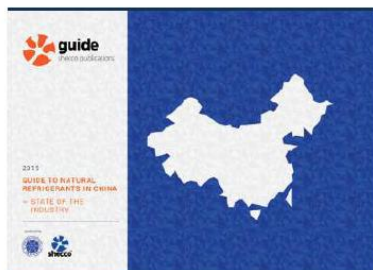
Energy level reduction
5%-15% kWh/100 lbs



Energy efficiency standards driving shift to hydrocarbons

The DOE energy conservation standards will bring about a large reduction in energy consumption. The standards with a compliance date of March 27, 2017, are to save approximately 2.9 quads of energy and result in approximately \$11.7 billion in energy bill savings for products shipped from 2017-2046. These energy savings translate into roughly 142 million metric tons of avoided carbon dioxide emissions. It has been suggested that to meet these energy efficiency requirements in small applications, companies are likely to shift their products to hydrocarbons, which have significant energy-saving properties.

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Shining stars of natural refrigerant promotion

THE GOLDEN STATE: CALIFORNIA LOOKING TO IMPOSE AMBITIOUS REGULATIONS

The state of California, the leader when it comes to environmental legislation in North America, has committed to reducing emissions of fluorinated gases by 80% by 2030 in new refrigeration and air conditioning equipment. To achieve the emissions reduction target, the Air Resources Board (ARB) is currently exploring possible paths it could take, which should complement the federal-level EPA SNAP and DOE regulations, but which will be more “aggressive” and could even outstrip the ambition level of the EU F-Gas Regulation.

A wide array of possible measures is being considered, including bans on high GWP HFCs, gradual phase down of HFCs, fees on high-GWP refrigerants as well as financial incentives for early adopters of low-GWP technologies. With an ambitious action California seeks to push the market forward, benefiting both its industry, which will become advanced in energy efficient and natural refrigerant-based technology out of requirement, but also their citizens who will feel the positive benefits of reduced GWP pollution. ARB is working on proposals for new measures in collaboration with the industry and other parties, and the final Strategy is expected to be published by Spring 2016.

As one of the measures adopted to implement AB 32, the California Global Warming Solutions Act of 2006, the Refrigerant Management Program has been introduced in California as the nation's first comprehensive regulation for reducing high-GWP refrigerant gas emissions from commercial and industrial refrigeration systems. The regulation focuses on large refrigeration systems using more than 50 pounds of CFC, HCFC, or HFC refrigerant. As of 2011, the regulation requires leak inspection, repairs, required service practices, and record keeping. In cases where systems cannot be repaired, a retrofit or retirement plan is required. Depending on the type and size of refrigeration systems, leak inspection requirements vary from automatic leak detection system to quarterly or annual

inspection. In addition, as of 2012, annual registration, reporting, and fee requirements apply for installations using fluorinated gases. Facilities using low-GWP refrigerants such as ammonia or CO₂ are not subject to the regulation and the compliance costs it entails.

Besides strengthening state-level regulations on HFCs, California will build on its partnerships with other countries and regions to encourage further emissions reductions.



Shining stars of natural refrigerant promotion

LA BELLE PROVINCE: QUEBEC MAINTAINS ITS BEAUTY WITH INCENTIVES FOR CO₂ REFRIGERANT

Quebec has the highest concentration of transcritical CO₂ systems in both commercial and industrial sizes, as well as the highest number of low-charge ammonia systems in North America. These two types of systems have seen the most dynamic developments in the region in the last few years, a trend which is expected to continue. Alongside Quebec's 94 CO₂ transcritical stores, there are over 90 "next generation" industrial refrigeration installations. These include 56 low-charge ammonia installations, 34 CO₂ transcritical systems and 5 CO₂/NH₃ secondary systems.

The availability of incentives for companies to use energy efficient systems such as natural refrigerant-based equipment has propelled the province to be a market leader in the adoption of natural refrigerants for commercial and industrial refrigeration. In the first phase, the Refrigeration Optimization Program (OPTER) supported the adoption of measures to improve energy efficiency, together with the conversion/replacement of refrigeration equipment to low-GWP technologies, in over 130 installations (mainly supermarkets, warehouses, arenas and the food industry) between 2008-2013. As of 2013, the incentive scheme continues under the "EcoPerformance" until March 2017, in which only implementation projects using CO₂ as a refrigerant are supported.

Besides providing direct financial incentives to accelerate introduction of climate friendly technologies, Quebec has revised its regulation respecting halocarbons and broadened the scope to introduce requirements on HFCs in the refrigeration and air conditioning sector.





Industry viewpoint

ON THE GROWTH OF NATURALS...

Joseph Kokinda –

CEO, Professional HVAC&R Services Inc

More has changed the last 10 years than has in the prior 50 relative to energy savings and climate change. Nanotechnology, the Internet of things and connected communities have all taken up their causes. The spread of knowledge via technological means has proven to be the major factor of advancing the natural refrigerant cause.

Tristram Coffin –

Sustainable Facilities Coordinator , Whole Foods Market

There's no silver bullet with natural refrigerant systems; we're looking at a variety of designs in different climate zones and building types.

Kurt Liebendorfer –

Vice President, EVAPCO

There is a wave coming for low-charge ammonia packaged solutions in the next 18 to 24 months.

Harrison Horning –

Director of Energy and Facilities, Hannaford Supermarkets

We see rapid growth in the number of natural refrigerant installations in the next five years. Some chains are already rolling out cascade systems. With transcritical systems, we expect more pilot projects; then we can expect activity to ramp up as certain applications achieve cost-effectiveness. The big question is how to deal with all of the existing installations. Natural refrigerant systems are much easier to consider for new installations than for retrofitting existing installations. As retrofit solutions are developed, the number of installations could increase dramatically.

ON TRAINING...

Arthur Miller –

Region 2 Director, RSES

Since 2012, we've trained approximately 1,500 people in hydrocarbons as of June 2015, and demand and inquiries for RSES's training services have tripled since the regulation [on hydrocarbons] was introduced in March.

Jim Price –

Former President of RETA

As the refrigeration industry in the U.S. evolves towards more regulatory compliance requirements as well as increased use of natural refrigerants other than ammonia, the training of technicians to work with new and innovative systems would need to update not only the content of the training but also the delivery methods.

Ian Crookston –

Manager of Energy Management, Sobeys

Lack of trained installation/maintenance technicians has been our primary challenge. To mitigate this, we work with system manufacturers that are committed to training the installation/maintenance technicians and reviewing any feedback they provide to improve their systems. With this level of open communication, everyone wins.



Innovations for all fluids

Güntner's improved and re-designed condenser and air cooler series are now optimized and precisely geared to the respective refrigerants and fluids. The tube diameters and materials in combination with the fin geometries constitute the optimum of both capacity and minimal tube volume. Specifically with regard to natural refrigerants like CO₂, air coolers offer operating pressures of up to 80 bar as standard, even 120 bar in the case of gas coolers. As always with Güntner, a wide range of accessories is available for the new series.



www.guntnerus.com

An ecosystem approach

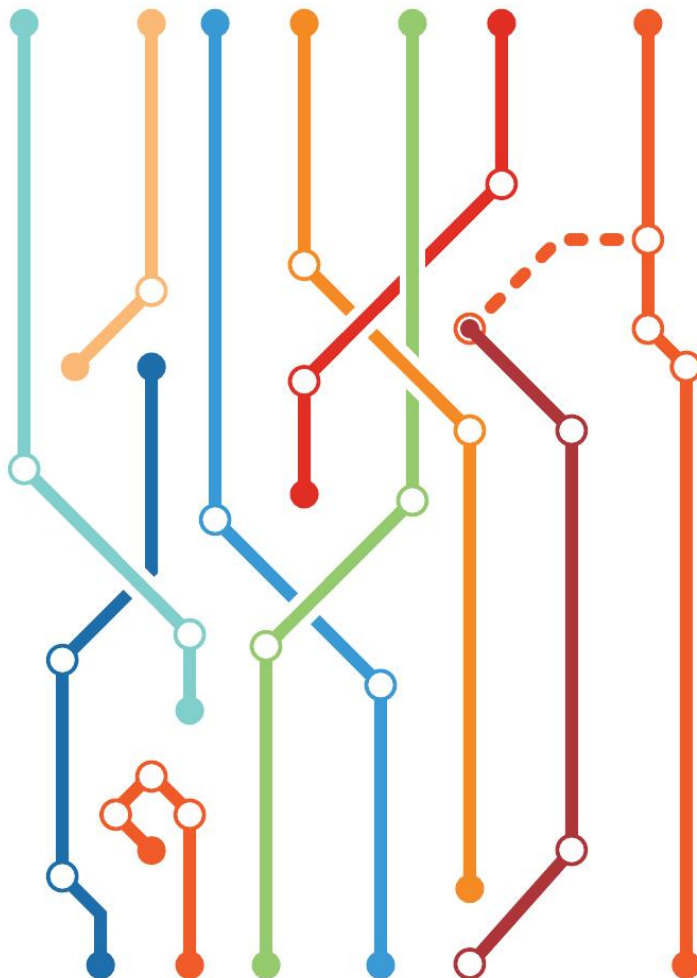
The purpose of the “ecosystems” is to highlight the recent developments in a variety of natural refrigerant-based products and technologies currently in use in North America. The examples mentioned aim to provide insights into the experiences of a range of North American manufacturers, suppliers and contractors, as well as end users, that drive the adoption of natural refrigerant-based technology. The cases highlighted also allow for a deeper analysis of the different business models currently used in various HVAC&R sectors in North America.

CITY & BUILDINGS: Natural refrigerants can be used in a variety of applications in public and commercial buildings, data centers, district heating and cooling and private residential housing. This section provides an overview of the latest application examples across North America.

TRANSPORT APPLICATIONS: The use of natural refrigerants is increasing in transport applications in North America, making the possibility of an all-natural supply chain possible in the future.

INDUSTRY, SPECIAL APPLICATIONS & SPORTS: Natural refrigerants are also applied in larger scale applications such as industry processing in laboratories, pharmaceutical, petrochemical industry, agriculture and power plants. Sports facilities such as ice rinks and ski halls in North America use natural refrigerants such as ammonia and CO₂.

FOOD CHAIN: Natural refrigerants are widely adopted in food and beverage storage, distribution, production and processing, and supermarkets. This section highlights different examples that use natural refrigerants.





Natural Refrigerant Compressors Heating Capacity... Efficiency...Sustainability

New Technologies Solving Old Problems

EcoThermics is applying high pressure axial piston hydraulic pump technology to compressors for transcritical CO₂ heat pumps up to a pressure of 2000 psi, roughly five times the pressure in traditional heat pumps.

The EcoThermics semi-hermetic, transcritical CO₂ compressor presents a scalable platform for a broad range of OEM specifications for commercial refrigeration, space heating and high-temperature water heating with ancillary cooling. Utilizing a “zero” environmental impact refrigerant (naturally occurring carbon dioxide), this unique axial, swash plate compressor is dynamically balanced to minimize noise and vibration, and operates at high-speed (3500 rpm) for increased capacity and significant benefit/cost advantages. A high-performance compressor with a small footprint (vertical orientation), this product offers dependable performance in a rugged, compact package, and a flexible, extended product line to service a wide application range.

www.ecothermics.com
Merle Rocke, CEO
309-303-0681
mrocke@ecothermics.com



City & buildings

PUBLIC AND COMMERCIAL

CO₂

Concordia University's Ed Meagher Arena, which has been in operation in Montreal since 1967, was renovated at the end of 2013. The renovations included a complete upgrade of the refrigeration system and an entirely new rink surface. Concordia University installed a transcritical CO₂ system, which does not condense CO₂ under high ambient temperatures; rather, the refrigerant leaves the compressor as a gas and remains a gas (albeit at a cooler temperature) when it rejects heat to the atmosphere. The new heating system in the arena employs this waste heat from the new refrigeration system. The installation means the arena can operate 11 months a year compared to seven with the former ammonia system. The system will also save the university \$40,000 a year on energy and maintenance costs.

H₂O

Desert Mountain High School in Scottsdale, Arizona, uses a solar cooling system featuring a 52,366-square-foot solar collector area which supplies heat to a single-effect lithium bromide absorption chiller with a cooling capacity of 1,750 kW. The project was launched in 2011 and now keeps 2,600 students and staff cool.

The chiller operates on full load during the hottest hours of the day, and during morning or evening hours the chiller is supplied with solar hot water between 149-167°F and is still able to deliver a substantial portion of the building's cooling demand under partial load. The system is able to cut down peak loads by precooling the back flow from the air-handling units, and the local utility company provides a subsidy per metered energy harvest in quarterly payments.

The Pennsylvania State Employees Credit Union (PSECU) constructed its new headquarters in Harrisburg, PA, completed in the fall of 2013. The facility uses natural gas-powered micro-turbines and an absorption chiller to provide 800 kW of power and 300 tons of chilled water to the data center. Heat exhaust from the micro-turbines is captured and piped either to an absorption chiller that provides a chilled water source for air conditioning in the summer, or to a heat exchanger that provides a hot water source in the winter. The cogeneration system is able to power nearly 100% of the building during off-peak and winter months, and 60% of the building during peak and summer months.

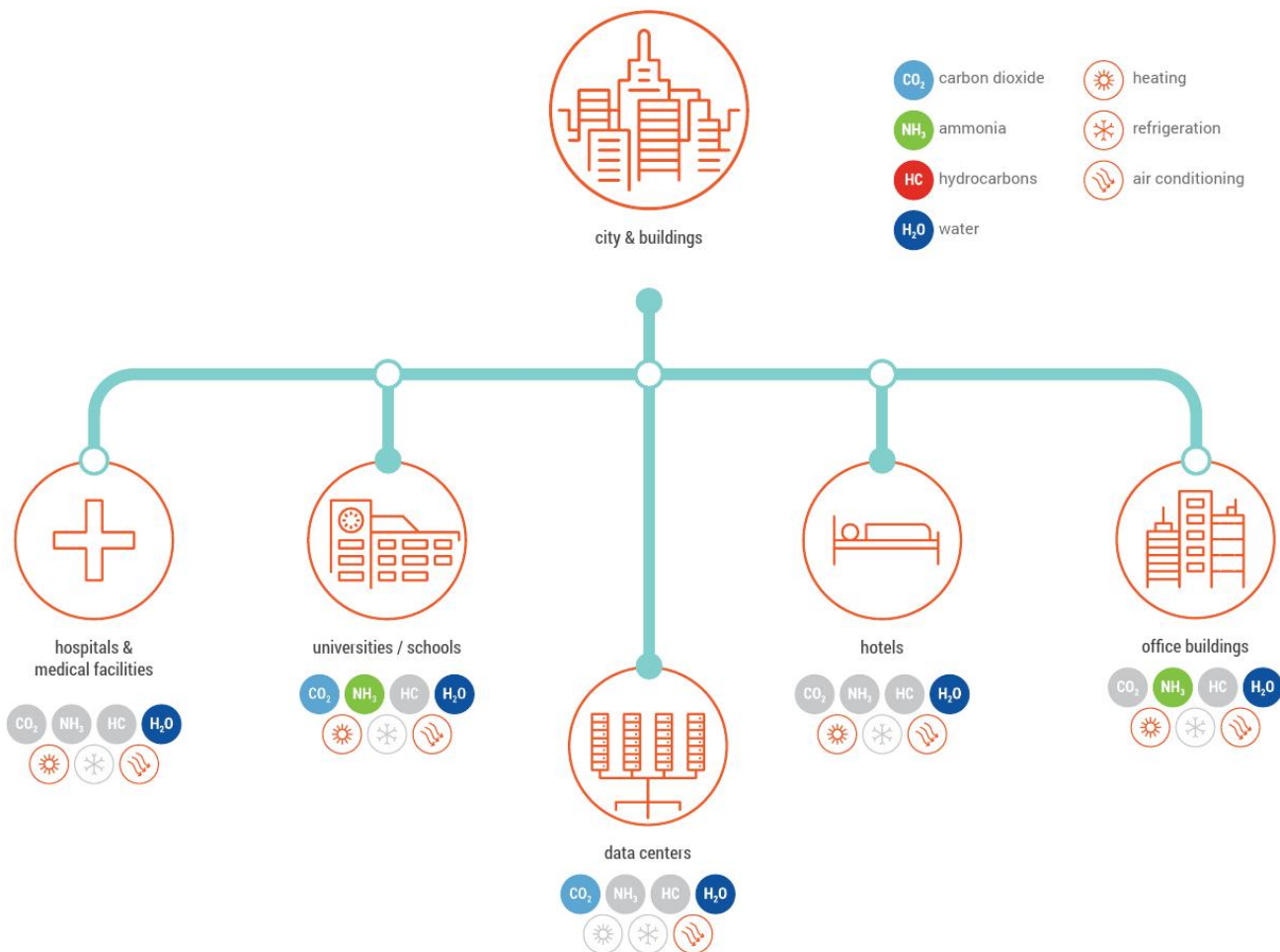
DATA CENTER

CO₂

Bell Canada installed a CO₂ transcritical refrigeration system to help cool their server room located in Ottawa. The CO₂ system has a cooling capacity of 105 kW that maintains the room temperature at 77°F. The system utilizes two semi-hermetic reciprocal compressors, an integrated control system and stainless steel piping. The system is able to withstand a pressure of 120 bar, meaning it can be shut down and maintain its refrigerant charge without issue.

H₂O

DataGryd designed a co-generation facility for 240,000 square feet of data center space in Manhattan. The absorption chillers reduce the amount of air-conditioning needed to keep the data center cool, thereby reducing electricity needs by 20%.



DISTRICT HEATING AND COOLING

H₂O

Carnegie Mellon University's Intelligent Workplace, located in Pittsburgh, provides 5,382 square feet of offices, meeting rooms and workspace for students and faculty. The energy supply system uses solar thermal energy and renewable fuel bio-diesel oil to drive a pair of 16 kW absorption chillers using water as a refrigerant to provide electrical power, cooling, heating and ventilation with temperature and humidity control.

Fort Knox army base in Kentucky, has installed four vapor absorption chillers for a combined heat, power and cooling project, part of the national energy security project implemented by the U.S. army. The chillers, triggered by waste heat and water, will cool a hospital, human resources center and an exchange building on the base. The system integrates renewable energy, grid power, energy storage, and load management to guarantee uninterrupted power, even in adverse conditions.

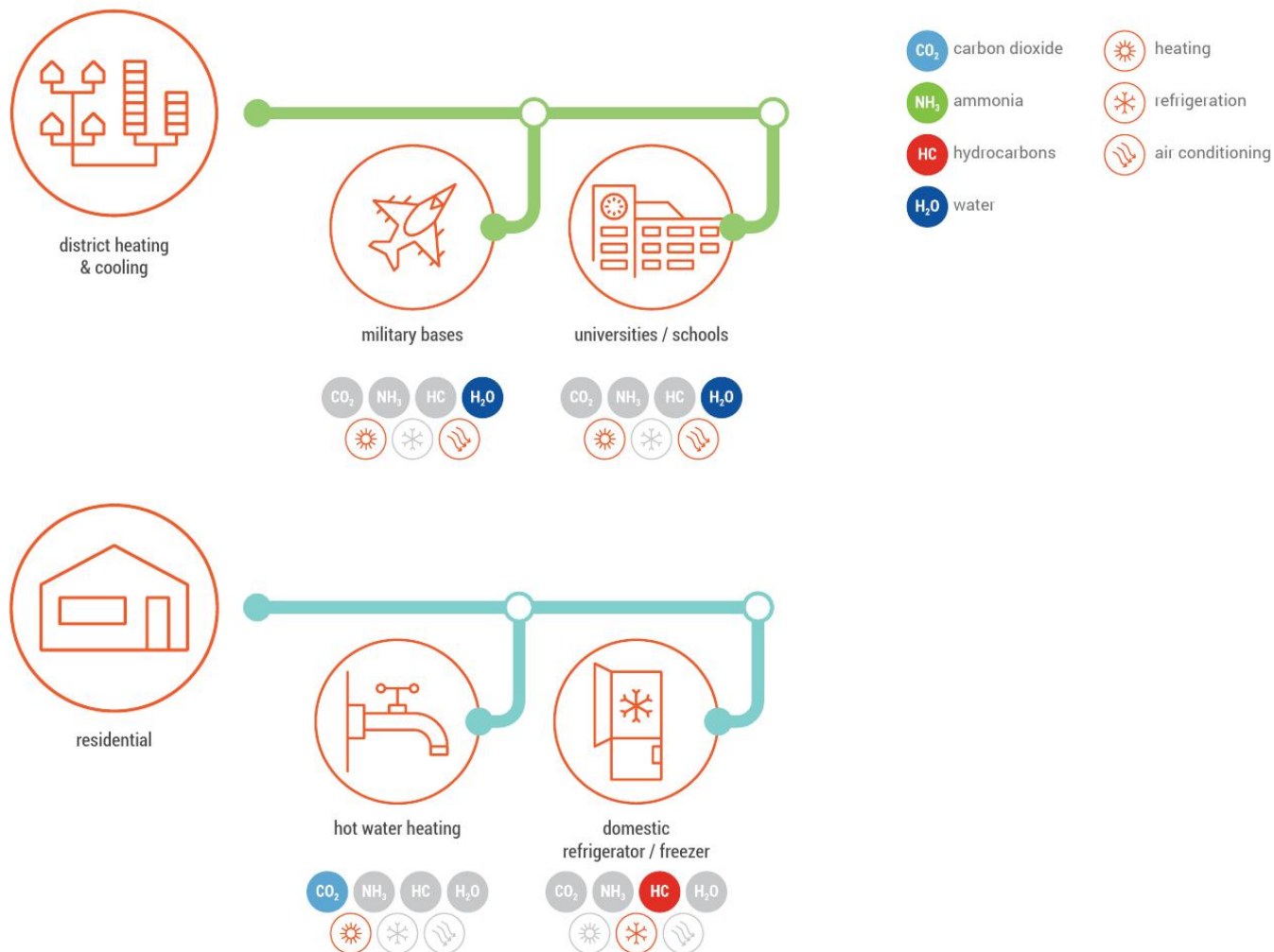
RESIDENTIAL

HC

In February 2015, the EPA made a final ruling, listing propane (R290) and hydro-carbon blend R441A as acceptable substitutes under the SNAP Program for use in room air conditioning units.

CO₂

A project led by the Energy Program of Washington State University and started by Bourneville Power Administration has been testing CO₂ heat pump water heaters for residential application in single-family homes in the Pacific Northwest. According to the test results, the CO₂ heat pump water heaters have shown an Energy Factor (EF) of 3.35 and Coefficient of Performance (COP) of 4.2 at outside ambient temperature of 67°F, compared to average electric resistance water heater with less than 1.0 EF and an HFC heat pump water heater with 2.4 EF. This means the CO₂ heat pump water heater is more than three times more efficient than the conventional electric water heater.



Transport applications

PASSENGER CARS, BUSES

CO₂

Effective from August 2012, the U.S. EPA made a final rule that lists R744 as an acceptable alternative with use conditions for motor vehicle air conditioning systems, including light-duty vehicles (passenger cars) and heavy-duty vehicles under 40 CFR (Code of Federal Regulations).

HC

Hydrocarbons can work as a primary MAC system refrigerant or in secondary loop systems. In North America, hydrocarbon refrigerants have been used as drop-in replacements for CFC-12 in an estimated 5 million car air conditioners,

though it should be noted, that no refrigerant should be used as a drop-in solution in a system for which it was not designed unless the system has been properly retrofitted. While in Canada there are no restrictions on the use of flammable hydrocarbon blends in passenger vehicle air conditioning, hydrocarbons are not approved as an acceptable substitute by the U.S. EPA's SNAP Program.

In 2009, collaboration between a U.S. and a German company resulted in North America's first all-electric, CO₂ refrigerant system for hybrid and electric transit buses.

REFRIGERATED TRANSPORT (TRUCKS, FISHING VESSELS, CARGO SHIPS, ETC.)

CO₂

In a notice issued on October 15, 2014, the EPA listed CO₂ as acceptable for use in new equipment in refrigerated transport without use restrictions. The listing will enable the manufacturers to pursue commercialization of CO₂-based transport refrigeration in the U.S.

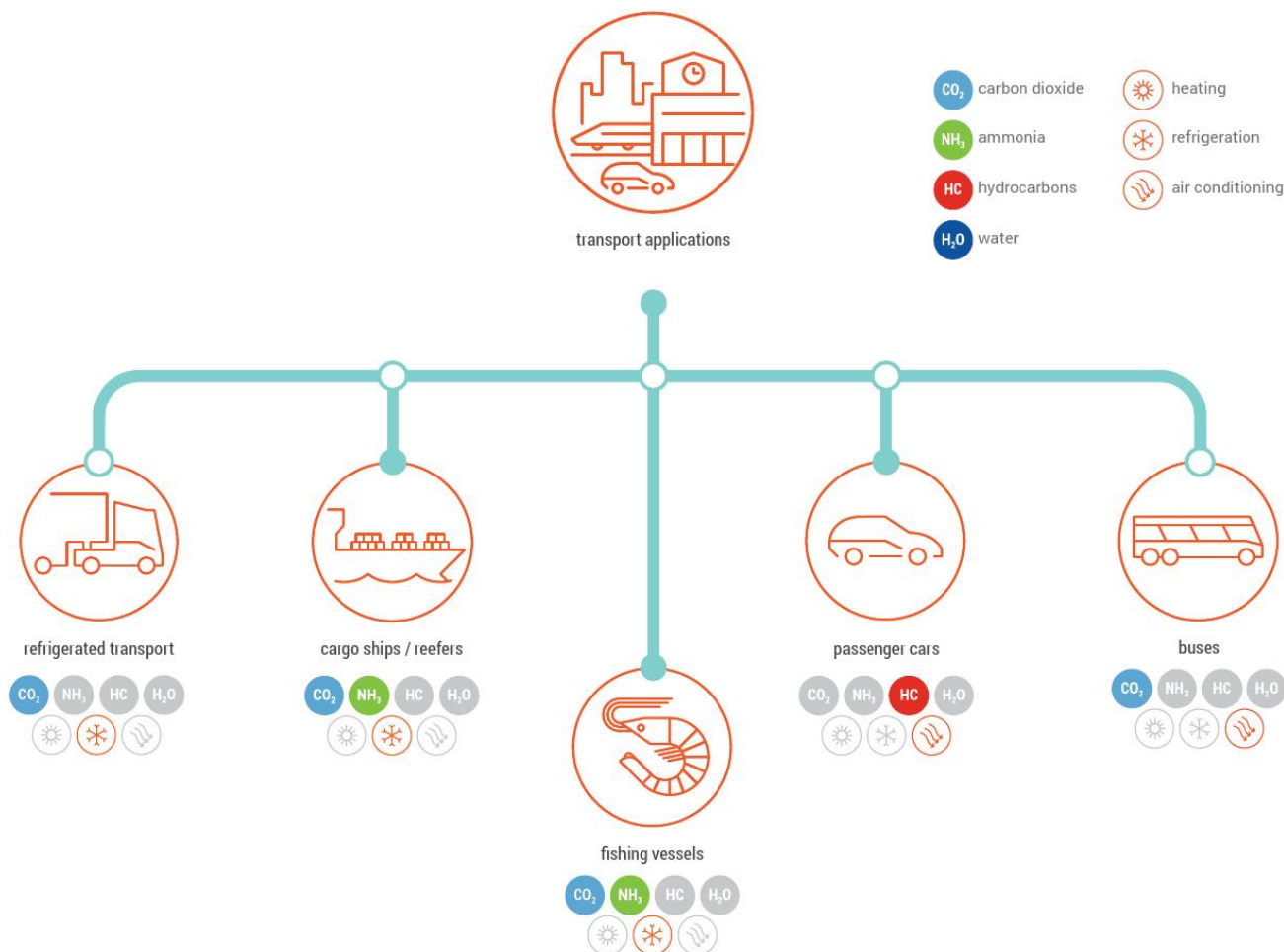
One leading HVAC&R system supplier made its CO₂ refrigerated intermodal refrigerated containers commercially available after having logged tens of thousands of hours in testing to prove efficiency and reliability in temperatures ranging from -7.6 to 55.4°F on Atlantic and Pacific routes. The system encompasses an innovative refrigerant management system including a patented multi-stage compressor with a variable speed drive, gas cooler and flash tank heat exchanger. The shipping container has since been modified to suit road transportation trials. The system received a RAC Cooling Industry Award in 2014 for refrigeration innovation.

Cryogenic systems using recaptured liquid CO₂ have been deemed acceptable substitutes for ozone depleting substances in transport refrigeration equipment under the U.S. EPA's SNAP Program. The cryogenic systems have few moving

parts to maintain and replace, allowing for near silent operation and quick recovery of thermostat set-point temperature after delivery stops. Typically, these systems operate by releasing the liquid refrigerant, held in pressurized tanks, through a spray nozzle at the ceiling of the trailer. The liquid CO₂ flashes into gas as it hits the warmer air in the trailer, absorbing the heat. Alternatively, the liquid CO₂ is circulated through a coil or plate heat exchanger and the vaporized gas is vented outside. A third type of system stores CO₂ snow in a full-length ceiling bunker and cools as the snow melts.

NH₃/CO₂

"American Freedom" is one of the world's largest reefer ships and uses a cascade refrigeration system that employs four ammonia screw compressors to generate a total output of 4,500 kW in a system that is charged with 3,307 pounds of ammonia and 22,000 pounds of CO₂. The system has a processing capacity of around 400 tons of sea fish per day and the fish that are caught are pumped directly into the hull of the ship, where they are shock frozen in 36 vertical plate freezers stored in cold stores in the hold.



Industry, special applications & sports

INDUSTRIAL PROCESSES AND LABORATORIES

NH₃

The substantial refrigeration needed for pharmaceutical production at Bayer's Berkeley site is provided by ammonia. The NH₃ system utilizes 18,700 pounds of ammonia, which is used in Bayer's process equipment refrigeration requirements. This is not uncommon as additional installations for similar processes are located throughout the U.S., with Roche's manufacturing facility in South Carolina uti-

lizing an ammonia refrigeration system to cool their state-of-the-art laboratories and production facilities as well as Abbott who use ammonia to cool its Nutritional Products Division in Arizona, where milk-based infant formulas and adult medical nutritional products are manufactured.

CONSTRUCTION

NH₃

Probably one of the most well known examples of a construction project where refrigeration plays an important role is the Hoover Dam. Completed in 1935, the dam was constructed by embedding nearly 120,000 yards of one-inch steel pipe,

which circulates ice water through interconnecting concrete blocks. The on-site ammonia refrigeration plant that cools the water is capable of creating a 450 kg (nearly 1,000 lb) ice block every day.

DEEP MINING

NH₃

In Timmins, Ontario, the world's deepest base metal mine, Kidd Mine, underwent development, which created "Mine D" (for deep), which provides a new reserve to replace ore from the three previously existing mines as they are depleted. The development presented the opportunity to update the ventilation system for all the mines. Started in 2004, the new strategy delivers energy savings as well as fresh

air, which must be kept under 82°F. The plant uses compressors, condensers, evaporators and ammonia refrigerant to indirectly cool water, which is used to cool the intake air for the mine. The indirect method protects underground workers any potential leak at the plant, which produces 17 MWR of cooling capacity for the mine.

BIOSPHERE

NH₃

Biosphere 2, constructed in 1991, is a unique 3.13-acre environmental research facility in Oracle, Arizona. Designed to explore the complex interactions within life systems, the almost airtight structure houses a variety of ecological systems.

Two mechanical ammonia chillers and an LiBr chiller provide cooling to help maintain varying temperatures in six biomes.

INTERNATIONAL SPACE STATION

NH₃

Aboard the International Space Station, the largest and most complex international scientific project in history, an ammonia coolant tank provides air conditioning

for crewmembers. In 2009, the ammonia tank was replaced, making the new tank the largest item ever moved at that time by astronauts during a spacewalk.

SPORTS FACILITIES

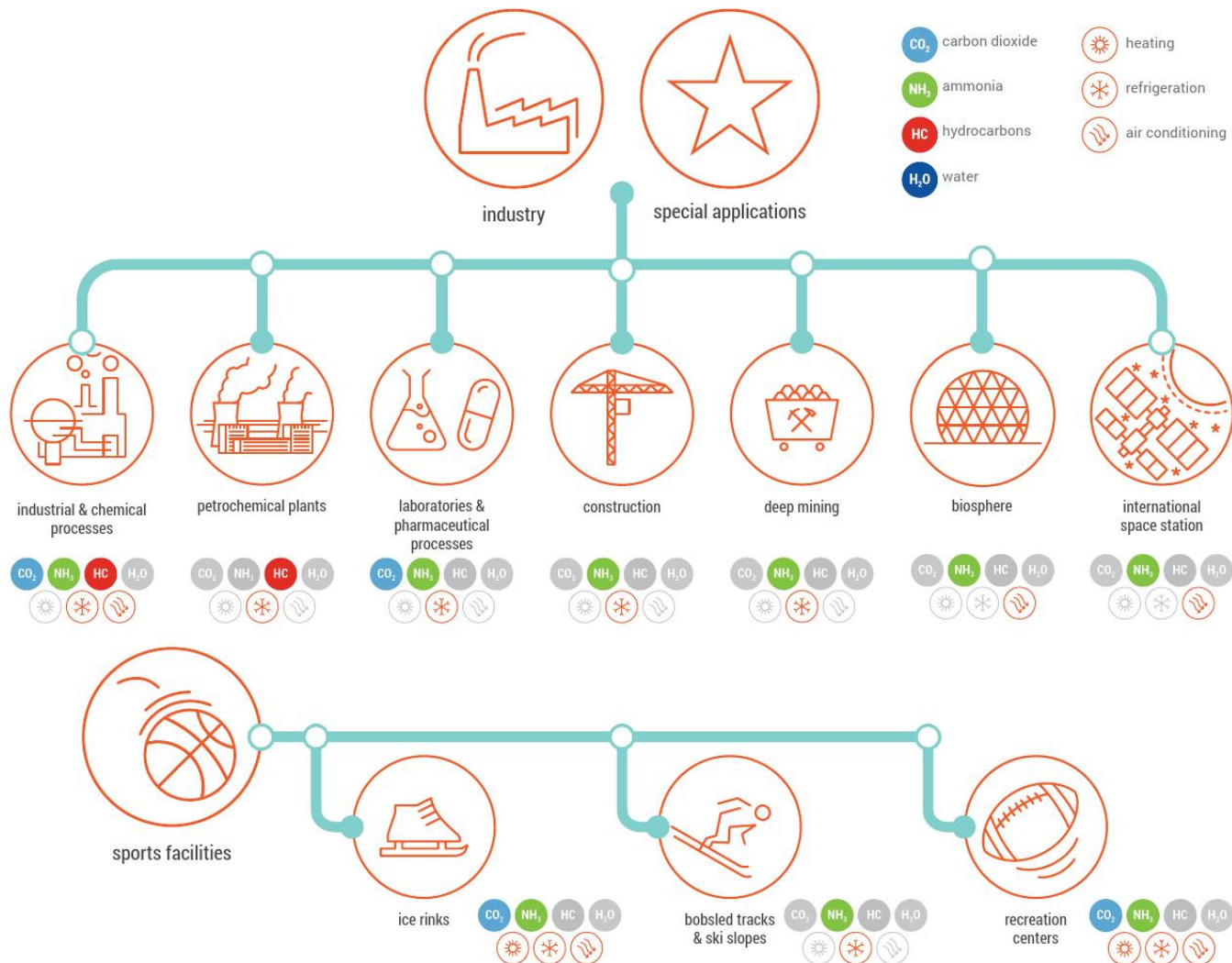
CO₂

In January 2015, the ribbon to the first CO₂ transcritical ice rink in the United States was cut in Anchorage, Alaska. The mayor of the city reported plans to extend the technology throughout Anchorage because it is more efficient and less expensive to operate. While the EPA has not approved CO₂ for use in ice rink applications, the Anchorage installation received approval as a pilot project, and the system supplier is confident that the success of the project will lead to full approval. The installation is anticipated to deliver energy savings of 25-40%. The CO₂ system has already lowered electricity bills and has significantly reduced spending on refrigerant.

The Dollars-des-Ormeaux sports facility complex located in Montreal replaced its old R22 system with a CO₂ transcritical refrigeration system. Not only does the new CO₂ system refrigerate three ice rinks, it also provides heat for two adjacent pools, a library and a gym through the use of waste heat. The complex –which totals 153,311 square feet– previously required 14 million kWh/year, but after one year of operation, the energy consumption was reduced by 33.4% while the heating expenses have declined by 81% compared to the previous system. Additional benefits to the complex include: 60% less space required for refrigeration equipment, 10% reduction in maintenance costs and no cool water tower required.

NH₃

The Westhills Recreation Centre in Langford, British Columbia, is a 75,000-square-foot facility consisting of an NHL-size indoor ice rink, an outdoor ice rink and a skating trail joining the two rinks together, as well as a 20-lane bowling alley, restaurant/lounge, party rooms, and 10,000 square feet of leased office space. The installation received a \$9 million grant from the Building Canada Fund. Despite the extensive energy use of the facility, only 40% of the waste energy is required within the complex while the remaining 60% is pumped 400 yards to a housing development as an energy source for household ammonia heat pumps. The payback on energy efficient features prior to energy sharing is around 2.81 years, with total energy savings of \$109,710.96 per year since the center's commissioning in 2012. The center has won a number of awards, including First Place ASHRAE Technology Award for New Public Facilities and First Place Northwest Parks as well as Recreation Facility Design Award.



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Food chain

FOOD PROCESSING

NH₃

Umpqua Dairy, the largest independent dairy in southern Oregon, recently remodeled its refrigeration system to keep up with increasing demand. The renovation included reducing head pressure on the refrigeration systems, installing evaporator fan cycling controls to maintain temperatures with less energy, replacing the ammonia system's two smaller compressors with a larger and more efficient compressor, adding a condensing unit and a variable frequency drive on energy efficient motors, and installing a PC-desktop control system. The project cost \$65,210 and qualified for \$16,067 in Energy Trust incentives. The changes are expected to save more than \$7,500 in electricity costs a year and 176,621 kWh. According to Pacific Power, Umpqua Dairy's new energy practices will also avoid the release of 10,488 pounds of carbon dioxide a year.

OSI Group's meat processing plant in West Jordan, Utah, has chosen a highly energy-efficient cooling system - using ammonia - to continue supplying its customers with quality products. Ammonia comes into play after the meat has

undergone the fermentation process. After fermentation, robots transport the meat to drying houses where it remains for a week. It is in these drying rooms that ammonia refrigeration is put to good use. The meat stays in these rooms so that it will achieve the necessary water activity level, moisture protein ratio (MPR) and other quality attributes. The West Jordan site was recognized by the American Meat Institute for its sustainability standards and has received several of the highest safety citations in the industry for developing a safe and healthy workplace.

NH₃

Eastern Fisheries installed a new processing line in its New Bedford, Massachusetts plant that will process up to 6,500 pounds of scallops per hour. The line also features a clean-in-place system that reduces cleaning time, a glazing tank, a raised freezing cabinet said to eliminate frost penetration into the foundation floor, and a gentle in-feed that maximizes yield. The system utilizes an ammonia cascade system.

FOOD STORAGE & DISTRIBUTION

NH₃

An ammonia installation that replaces an R22 refrigeration system destroyed by a fire at Viandes Meats, a meat packing plant in Quebec, has a capacity of 2,500,000 kWh and provides 1,327 kW of heat. The NH₃ installation is comprised of one spiral freezer at -40°F, five blast freezers from -40 to -10°F, one freezer at -10°F, 24 medium-temperature rooms from 36 to 50°F, and four hygienic preparation rooms at 36°F. The installation saves 260 kW of hot water heating, 1200 kW of electric heat, 62 kW of air conditioning and 200 kW of refrigeration. The installation received a \$500,000 grant from Hydro Quebec.

CO₂/NH₃

In California, a cascade CO₂/NH₃ system installed in a public refrigerated warehouse was compared through intense monitoring and tests to a more conventional refrigeration system operating with R507. The study found a 3% energy cost savings and 67% reduction in total equivalent warming impact (TEWI) for the CO₂/NH₃ cascade system compared to the R507 2-stage system.

THE POWER OF BRAINS

A machine is only as good as the engineer who built it



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CD Range results from more than a decade of experience and more than 12.000 running transcritical compressors on the field. Reliability and efficiency make these compressors the natural solution for sustainable HVAC&R market. Dorin naturally broaden the Range with the CD500, a 6-pistons Range that takes the maximum displacement of Dorin CO2 Transcritical Compressors from 30,23m³/h to 53,20 m³/h.

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CO₂

In October 2014, United Natural Foods, Inc. (UNFI) opened a new distribution center in Montgomery, New York, which provides its Metro New York, Long Island and New York customers with its wide range of natural and organic food products. The 500,000-square-foot distribution center is the second largest UNFI facility in the East Region. The center was designed and constructed using sustainable practices, including environmentally friendly refrigeration systems employing CO₂ refrigerant. The building is expected to achieve energy use reduction of 26% compared to a comparable building.

In July 2015, Nestle opened a 144,000-square-foot research and development facility in Solon, Ohio, costing more than \$50 million. The R&D facility utilizes a CO₂ transcritical refrigeration system in a pre-engineered mechanical enclosure.

HC

A fruit company in Washington recently installed two packaged chillers using propylene (R1270) as the primary refrigerant in the secondary system. The chillers feature high-efficiency and a low-net-weight charge and are able to maintain the perfect temperature for 7,500 tons of apples.

WINERIES & BREWERIES**CO₂**

Wine producer Somerston Wine Co, located in the Napa Valley, California, completed a state-of-the-art, energy-efficient winery featuring the first-ever integrated CO₂ heating and cooling system. The system features electric-driven hot water heat pump that uses CO₂ refrigerant for glycol cooling and hot water heating. The heat pump can achieve 194°F hot water output temperatures, far outperforming HCFC and HFC refrigerant heat pumps, which only achieve 160°F output at best.

The system has been in operation since late 2010 and, when compared to a more traditional system, a 22% energy reduction was achieved. In addition, the heat pump can source heat from either the glycol cooling loop for low-load conditions or from the higher temperature water cooled condenser of the electric chiller for increased COP and system performance.

SUPERMARKETS**CO₂**

In Dunwoody, Georgia, the most southern transcritical CO₂ booster system in North America made its debut at the opening of a Sprouts Farmers Market in July 2014. The supermarket is approximately 29,000 square feet and features a standard CO₂ transcritical rack with 4 MT and 2 LT compressors. The system also employs an adiabatic gas cooler to increase efficiency of the refrigeration system in the warm Georgia climate.

In October 2014, Metro Plus Marquis opened a 45,000ft² store, for which it received a \$25 million investment, using a CO₂ transcritical refrigeration system in L'Assomption, a suburb of Montreal. The retailer reports greater energy perfor-

mance than standard systems, due in part to electronic controls offering full optimization. In addition, the system design allows waste heat from the compressors to be recovered and used to heat the store.

Angelo Caputo's Fresh Market opened a 300,000 square foot combined warehouse, commissary and retail store in Carol Stream, Illinois. Installed in the building is a CO₂ transcritical system, one of the biggest in the U.S., which provides cooling for food preparation, the warehouse and the 100,00-square-foot store, setting it apart from the transcritical installations in conventional grocery markets. Three of the transcritical system's racks were installed in the warehouse

and commissary near the end of 2013 and the fourth was installed in the retail store in 2014. According to the supplier of the system, in the 49°F average annual temperature of the Chicago suburb, transcritical CO₂ systems can operate 5-10% more efficiently than conventional DX systems.

In the U.S., the Target Corporation has trialed CO₂ systems in five stores, and in June 2014 officially announced that it is changing its prototype for new stores from R404a to cascade R134a/CO₂ systems. The latter have a 65% lower carbon footprint and increased energy efficiency compared to the company's conventional model. The systems reduce the amount of HFC refrigerant from around 1,000 to 500-600 lbs. Target plans to open two more stores with the prototype system in 2015 in Lake Bluff, Illinois, and Ft. Worth, Texas.

NH₃ / CO₂

A remodeled 117,000-square-foot commissary at the Lackland Air Force Base in San Antonio began operating the first phase of an NH₃/CO₂ cascade system in November 2014. The system is now fully operational except for the part serving the produce department, which is still under renovation. The commissary is managed by the Defense Commissary Agency (DeCA), a global chain of supermarkets for the U.S. military, with 250 supermarkets currently in use on military bases, generating approximately \$6 billion in annual sales. The initial-cost differential between the NH₃/CO₂ system and an R404A system proved less than expected –\$334,000, including equipment, installation, piping and refrigerant. The NH₃/CO₂ system is projected to use 7.9% less energy compared to a four-rack R404A DX system, a saving of \$3,100 annually. In addition, the annual maintenance cost savings, attributed to reduced refrigerant costs, are estimated to be \$5,500 annually.

LIGHT COMMERCIAL REFRIGERATION (ICE CREAM FREEZERS, BOTTLE COOLERS, DISPLAY CABINETS, ICE FLAKE MACHINES)

HC

In 2008, 50 Ben & Jerry's hydrocarbons cabinets were placed in Washington, D.C., and Boston under the U.S. EPA's Clean Air Act alternatives policy, and in 2009, Ben & Jerry's submitted its application to the Significant New Alternatives Policy Program, receiving approval in 2011. By 2012, the company rolled out at least 700 freezers and planned in 2013 to roll out another 700 hydrocarbon freezers, reducing CO₂-equivalents by approximately 130 tons. Today, Unilever (Ben & Jerry's parent company) has more than 133,000 HFC-free freezers throughout Canada, the U.S. and Mexico.

As of March 2015, Red Bull has deployed nearly 60,000 hydrocarbon ECO-Coolers in North America, and more than 500,000 worldwide. The company's ECO-Coolers uses 45% less energy than conventional HFC refrigerators.

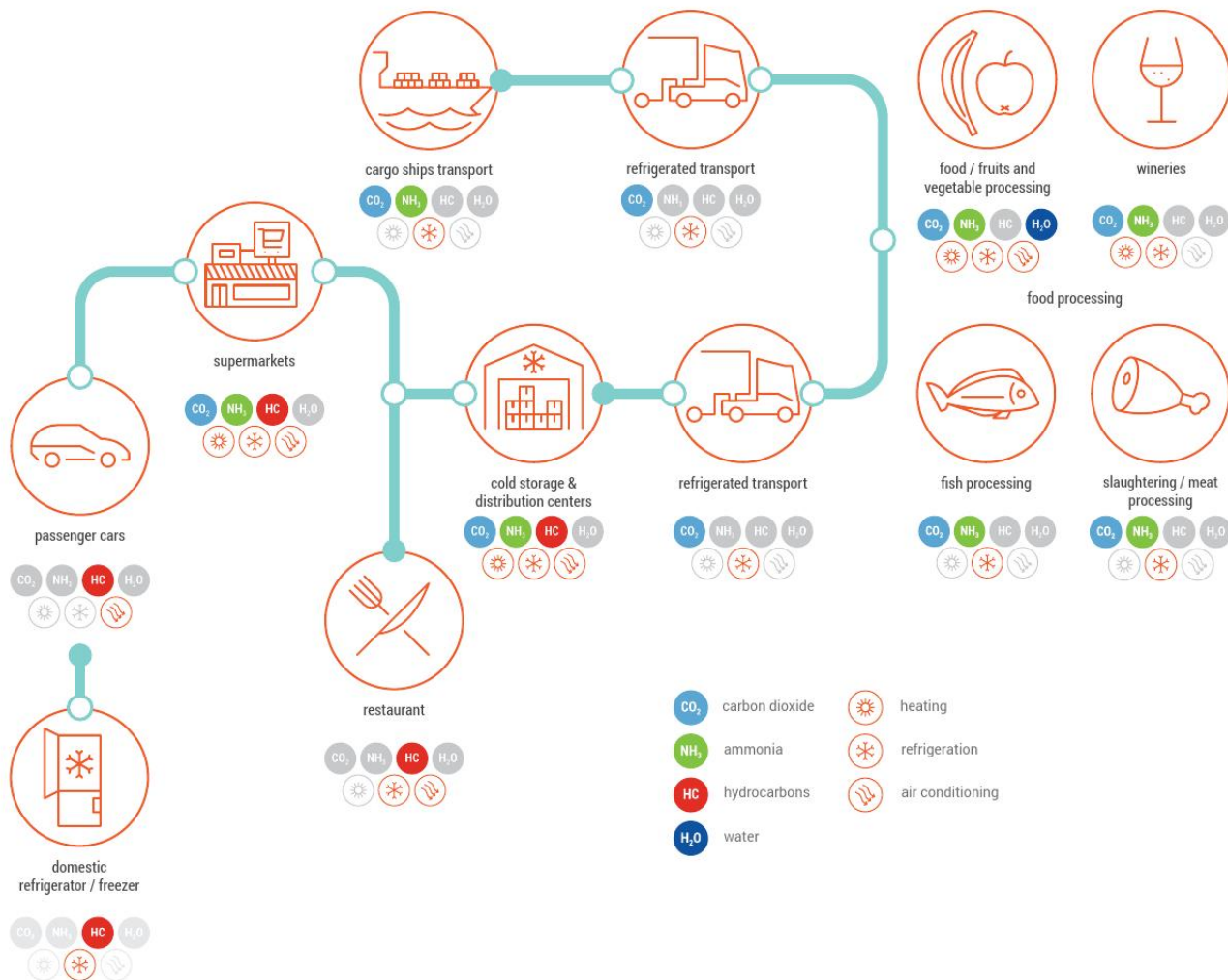
Lowe's Markets recently installed – in a remodeled 34,000-square-foot store in Lubbock, Texas – a number of frozen food cases, on top of which are one of two types of condensing units: one with 4.3 ounces of propane serving two-door cases and one with 5.1 ounces serving three-door cases. In total there are 35 condensing units and 170 ounces of refrigerant. While data collection is still ongoing,

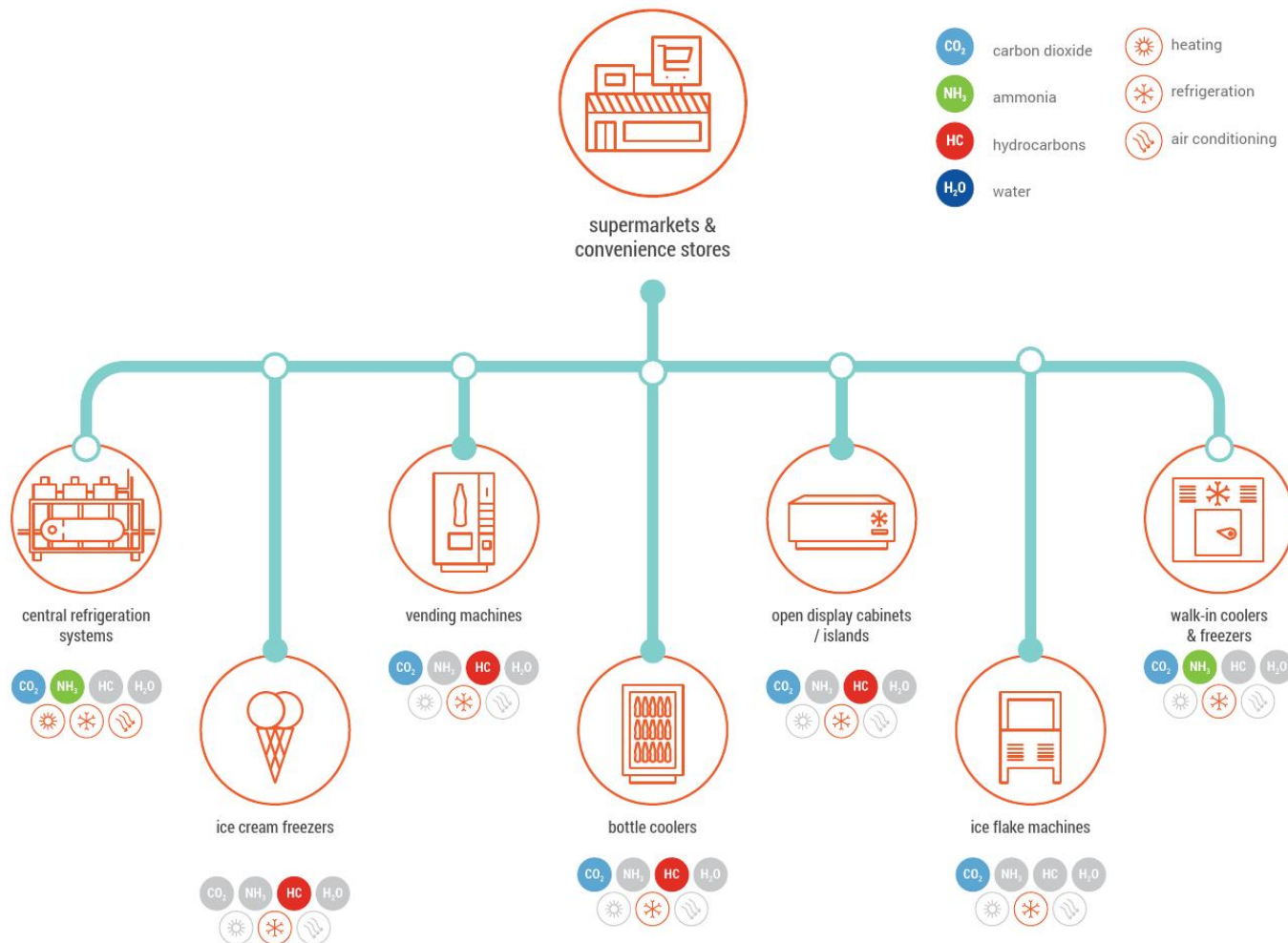
it is expected the cases will meet or exceed 10-15% reduction in energy, compared with a low-temperature DX system.

CO₂

In 2009, The Coca-Cola Company set an ambitious goal to phaseout HFCs in new cold drink equipment as of 2015. To date, 1.5 million HFC-free units using either CO₂ or hydrocarbons have been placed globally, including 12,354 CO₂ cabinets in North America. According to research by the U.S. Department of Energy and Energy Star laboratories, CO₂ systems are more energy efficient than R134a systems.

Roche Bros. opened its flagship store in downtown Boston in late April 2015. The 25,000-square-foot market offers the growing neighborhood fresh food, national grocery brands, regional and local flavors and a selection of prepared foods and uses a CO₂ liquid-overfeed refrigeration system, which cools refrigerated and frozen-food applications throughout the store, including a CO₂ flake ice machine in the seafood department. Other leading retailers, such as Sobeys and Whole Foods are also deploying CO₂ ice machines to keep food products fresh.





Natural refrigerants used outside North America

While the ecosystems on previous pages show the increasing number of applications that are beginning to use natural refrigerants as well as those that have already fully embraced them, there still remains room for improvement. The “Outside North America Ecosystems” section gives concrete areas where natural refrigerants have not been deployed in North America or only to a small extent, but where there exists significant growth potential for natural refrigerants. This section, using the example of success stories from other regions serves as an indication as to where the use of natural refrigerants may be expanded in North America in the future.

City & buildings

PUBLIC AND COMMERCIAL

HC

Eight 650 kW water-cooled water chillers using hydrocarbon refrigerant R290 were installed at the Co-operative Group's new headquarters in Manchester, the largest ever propane chiller project in a commercial building in the UK. The building has achieved the highest BREEAM rating, receiving the ‘Outstanding’ accreditation for a large, commercial building in the UK.

CO₂

The use of Eco Cute, a CO₂ heat pump water heater, in Japan has reached 4.7 million units as of February 2015. Annual sales are now reaching 400,000-500,000 units, meaning a market share of 98% of all new heat pump water heaters. This is set to double by 2020, with the Japanese Government aiming to reach 10 million Eco Cute CO₂ heat pump water heaters. While in China, the use of CO₂ heat pump

water heaters is still in its infancy at roughly 300 units, its use is expected to grow with estimates of 50,000 units installed in China by 2020.

Bumade railway station in China uses three 50 kW CO₂ heat pumps to provide space and water heating for its 32,292-square-foot maintenance area. The project is especially notable because the railway station stands 15,748 feet above sea level. However, it is not just the height which is extreme; the heat pumps work well even during Bumade's winter period when the outside temperature can be as low as -86°F, the coldest operating temperature for this type of project in China. Because of the high energy savings and stable performance of the project, 24 CO₂ heat pump units were installed to provide space heating in another five railway stations on the Qinghai-Tibet railway line.

DATA CENTER

HC

A cooling unit using propane was installed in the Lübbecke public utilities in Germany. The R290 system supplies the cooling demand for the building air-conditioning and for the server room cooling, while at the same time helping to reduce operating costs.

RESIDENTIAL

HC

The use of hydrocarbons in domestic refrigeration has been used in European refrigerators and freezers for many years and has become a standard, with over 90% of new appliances containing hydrocarbon refrigerants. This trend is also apparent in Japan, where hydrocarbons were introduced into domestic refrigerators and freezers in 2002 and now dominate the market. With China also utilizing hydrocarbons in close to 100% of its new domestic refrigerators and freezers, this is a global trend that North America can implement.

Recent legislation by the Chinese Government has made room air-conditioning (RAC) a key application for natural refrigeration in China. This promotion is manifested in the complete conversion of three production lines, which have an annual production capacity of 400,000 units. In addition to this, there are 17 other RAC production lines currently being converted alongside four compressor production lines. As China manufactures 85% of global RAC units, this could become a global trend.

Transport applications

PASSENGER CARS, BUSES

CO₂

Regie des transport de Marseille (RTM), a French bus line operator, is moving to phase out R134a in its mobile air conditioning, running tests using CO₂ on two of its new buses in 2015. The system achieves energy savings due to CO₂'s superb thermodynamic properties, high volumetric cooling performance and good thermal transmission efficiency. Due to the higher pressures of CO₂ in an air conditioning unit, the system and all its components require a customized design

optimized for CO₂. With the many innovations found in this bus, it is expected this system will extend the buses' operating distance by 40%.

CO₂ mobile air conditioning systems have also been installed in trains. Deutsche Bahn, a German railway company, began field trialing of this equipment in 2011.

REFRIGERATED TRANSPORT (TRUCKS, FISHING VESSELS, CARGO SHIPS, ETC.)

CO₂

A CO₂-refrigerated shipping container has been modified to be used in road refrigeration, the container was mounted to a box trailer and transported on land. Sainsbury's, a leading UK retailer, has been testing the unit for over a year across Greater London, with the system receiving a RAC Cooling Industry Award in 2014

for refrigeration innovation. These units reduce CO₂-equivalents by up to 35% compared to the previous equipment and it is believed that it will save Sainsbury's over 70,000 tons of CO₂ emissions compared to its current refrigerated trailer fleet.

CO₂ refrigeration is used in The Bergen Harbor's ship terminal in Norway, a UNESCO World Heritage Site. The terminal utilizes a CO₂ refrigeration system specifically tailored to the needs of the ships at the terminal, which is used by Hurtigruten, shipping service as well as the other ships using the terminal. The terminal covers an area of 129,167 square feet and cost approximately \$25 million to

build. The refrigeration system is 100% CO₂, and was chosen as an alternative to the environmentally harmful R22. The cooling and freezing area covers an area of 44,132 square feet and is located on the mezzanine above the loading bays on the landsides for cargo from the ships. The excess heat from the cooling and freezing areas is used to heat the terminal and offices.

Industry, special applications & sports

NH₃

Off the coast of Hainan in southern China, an Ocean Thermal Energy Conversion (OTEC) power plant is being constructed, with an expected completion date of 2017. OTEC represents a sustainable and continuous energy source that is capable of producing high levels of electricity. To do so, it utilizes the temperature difference between the warmer water found at the surface and the cooler water found lower down. The power plant will be configured as a closed-cycle system

and will be the world's largest OTEC facility. Without using fossil fuels, and using ammonia as a refrigerant, the system meets electricity demand by harnessing solar energy that the seawater has absorbed. The completed power plant will generate electricity that will supply a resort built by the Reignwood Group on the Hainan Island.

Food chain

FOOD PROCESSING

HC/CO₂

A meat processing plant in Osnabrück, Germany, uses a propane-CO₂ cascade system for refrigeration and deep-freezing, in processing and cold storage applications. The system uses propane as a refrigerant in the plant room and propylene glycol to distribute the cold in temperatures ranging between 37.4°F to 17.6°F. The refrigeration supply in the deep-freezing unit features CO₂ direct evaporation at -89.6°F. The cooling capacity is 80 kW for refrigeration and 8 kW for deep-freezing. The newly integrated CO₂/propane system reduces the required space and assembly efforts, leading to reduced investment costs.

CO₂

CO₂ transcritical refrigeration systems have been installed in fishing vessels in Europe. The cooling and freezing compressors are mounted on one frame that includes oil systems, tanks, pumps and everything else needed, allowing for instant freezing on the vessel through its plate freezers. The plate freezers, which use CO₂, provide a high freezing rate in addition to shorter freezing times, saving energy. It also has the added benefit of preserving the natural quality and freshness of the fish.

Air

At Sea Sky Global's state-of-the-art tuna processing plant, located in Busan, South Korea, there are three units using air as a refrigerant to keep the company's 2,500 tons of raw tuna and processed products fresh. The system contributes to energy

and cost reductions, with electricity usage cut by 40%. As there is no need for defrost, there is little variation in temperature, ensuring that products remain fresh and as air is a harmless gas, the cost of safety is greatly reduced.

SUPERMARKETS

HC

Waitrose, a UK retailer, uses a propane-based refrigeration system in a select number of stores. The installations comprise integral cabinets and close coupled cold room systems that are interconnected by water piping, with the average charge of a single system around 1.5 pounds. The total on-site hydrocarbon charge is less than 220 pounds, with less than a 2.2-pound charge within the building and 220-pound charge located in the chillers outside. The propane-based fridges have helped cut its carbon footprint by 15%, their energy costs by 20% and cut servicing and maintenance costs by at least 50%

CO₂/HC

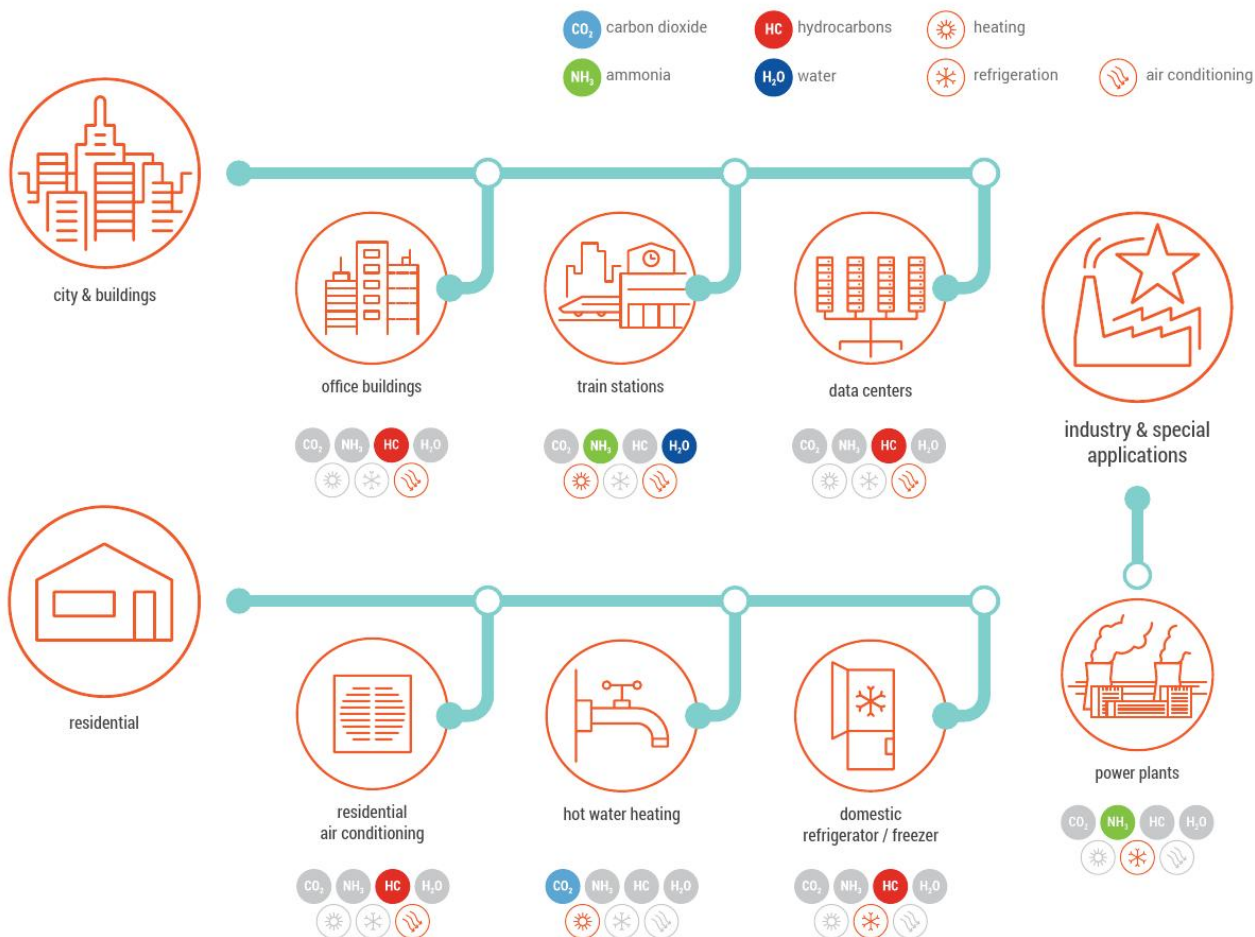
Since 2009, German retailer Lidl has relied on compact refrigeration units using propane for normal refrigeration, a heat pump for heating and CO₂ for deep-freezing. More than 200 units are in operation today, showing that propane is already suitable for series production. The compact refrigeration unit is designed to be cost efficient and environmentally friendly, producing the refrigeration needed to cool shelves, refrigerate counters, cold rooms, cold storage cells and for air-conditioning. It also generates floor heating and integrates the electro technical equipment for the whole store.

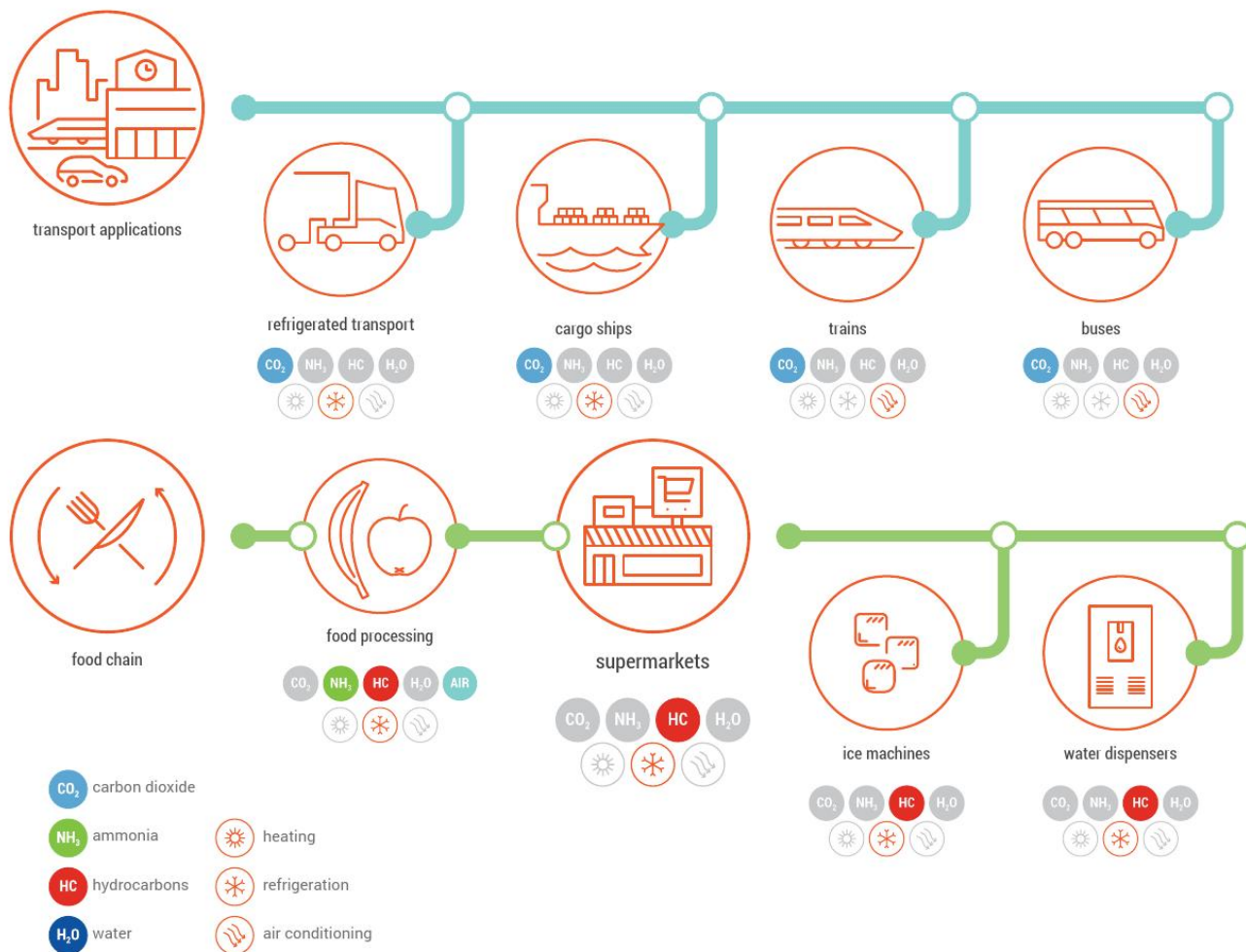
LIGHT COMMERCIAL REFRIGERATION (WATER COOLERS, DRINK DISPENSERS AND ICE MACHINES)

HC

The use of hydrocarbons in water coolers and drinks dispensers is currently not SNAP approved in the U.S. but are used widely in Europe, with both R290- and R600-cooled water models available.

Similarly, the use of hydrocarbons in domestic and commercial ice machines is steadily increasing in Europe. However, hydrocarbons are not yet approved for use in this application under the SNAP Program.







Outlook for natural refrigerants in North America TOMORROW

Introduction

With such notable progress since the previous GUIDE to North America in 2013, the future of North America's natural refrigerants market throws up a great number of opportunities for the increased use of natural refrigerants. This chapter serves as a navigation to how the industry is responding to the recent market development by analyzing the expected increase in R&D expenditure by 2020. The percentage of those not currently using or providing natural refrigerants, but who will be entering the natural refrigerants market, is also presented, including which refrigerant they plan to use and when they expect to enter.

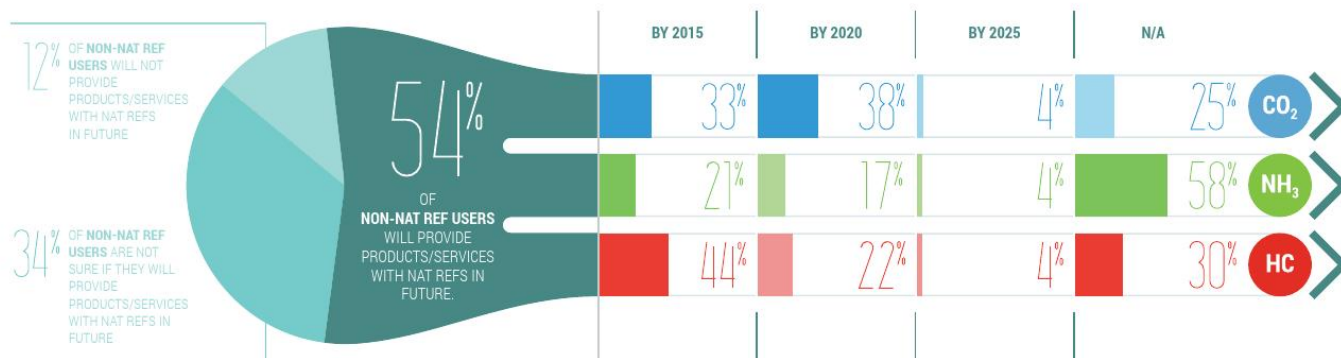
In addition this chapter presents a commercial availability chart, which gives a clear overview of the expected level of growth for a wide range of individual applications for the next fifteen years. This chart gives a coherent understanding of the projected length of time before less-recognized applications for natural refrigerant are developed, as well as providing detailed analysis of mature markets for natural refrigerants such as light commercial, commercial and industrial refrigeration. The chapter describes presents the ongoing policy changes that will have a major impact on the future of natural refrigerants in North America.

Future trends for natural refrigerants

Growing number of new entrants contributes to exciting future for market development

The finding that 54% of those who are not currently involved with natural refrigerants plan to invest shows the long-term viability of the market. With only 12% resolute in staying away from naturals, the majority are considering or have decided on a move. With regards to which refrigerant they will adopt, there is a more immediate appeal to hydrocarbons with nearly two-thirds of survey respondents looking to begin using these in the next five years, which may be related to the incoming DOE policies. The use of CO₂ is also a more immediate solution, with

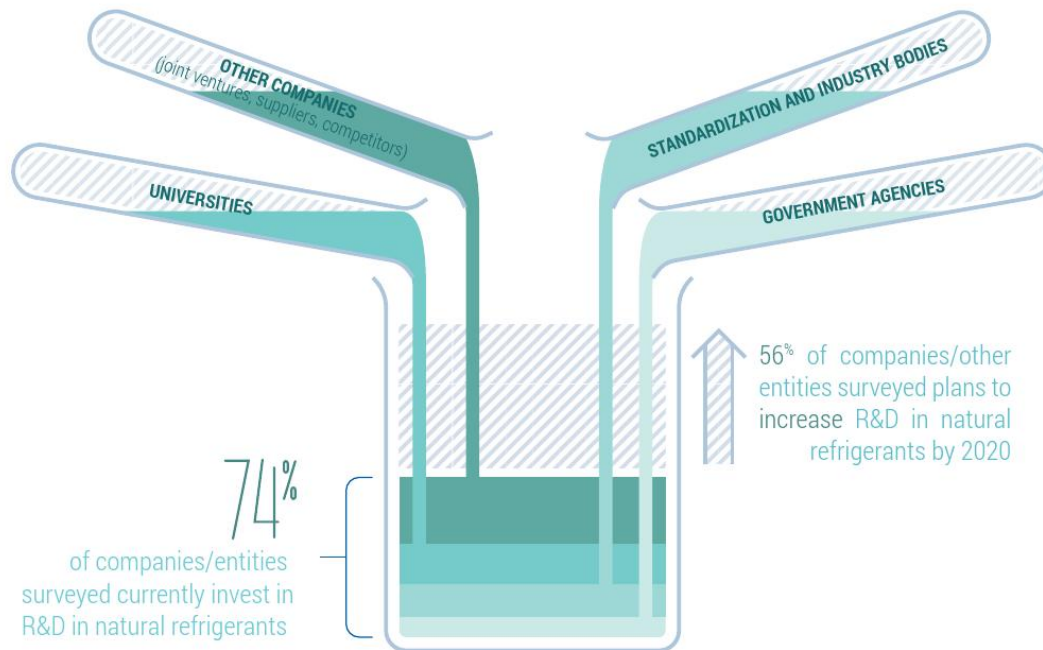
over 70% looking to use the refrigerant in the next five years; again this could be in accordance with incoming government policy, this time from SNAP. In Canada, the use of CO₂ transcritical is emerging as a standard for some retailers and could be encouraging the acceleration of adoption for others. With ammonia, the majority are undecided about when they will introduce the substance, however, as an already well-defined solution for industrial, this could be indicative of the clear direction for the market, but perhaps lack of definition.



R&D to increase in over half of companies surveyed

The current level of research and development shows the focus on the future that companies are already developing potential solutions for. This indicates that the industry is aware that policy will continue to tighten and to prevent falling behind and losing market share, that investment is required in natural refrigerants and the increase of 54% by 2020 shows that this trend will only get stronger. Currently the most common collaborator in R&D is other companies (37.4%), showing the level of cooperation within the industry as well as the technology transfer from Europe, where key manufacturers in North America have sister companies

in Europe. The second most common is universities (28.7%), while the third and fourth are standardization and industry bodies (28.7%) and government agencies (25.7%), which shows the interaction between the private and public sector that has been a hallmark of the Obama administration. Incentives from energy utilities and R&D funds from the DOE allow for new and exciting natural refrigerant-based technology to be explored. Private laboratories (21.1%) are also used for natural refrigerant R&D, as are freelancers and contractors (17%).



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- Sustainable and Energy Efficient
- Heat recovery leverages simultaneous heating and cooling to maximize effective COP
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- Reduced carbon footprint as compared to gas-fired boilers
- CO₂ refrigerant natural and non-toxic
- CO₂ refrigerant reduces global warming with GWP rating of 1



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Commercial availability in the U.S. by 2030

Growing influence of natural refrigerants in three key sectors

In order to showcase the current and future commercial availability of equipment using natural refrigerants in the U.S., shecco, in collaboration with a number of industry experts, analyzed the market and outlined the expectations in a sector-by-sector chart. Expert views were also collected during the ATMOSphere America 2015 conference.

According to industry experts, the technical feasibility of natural refrigerant-based systems in refrigeration and air-conditioning applications is not an issue; and energy efficiency can reach at least the level of HFC-based systems, if not higher. For those applications not currently at this level of development, it is possible to realize this potential through further research and development.

As well as confirming the commercial availability of both small and large industrial refrigeration equipment and the expected dates for the commercialization of both light commercial and commercial refrigeration. It also looks at the more ill-defined applications at work in North America and the likelihood of their adoption of naturals in the coming fifteen years.

The analysis shows that refrigeration applications using natural refrigerants are either already in the marketplace, or could become a widespread option in the 2016-2018 timeframe. Natural refrigerant-based equipment in the air conditioning sectors, however, will require a bit more time to hit the U.S. market.

The uptake of HFC-free technologies in applications where natural refrigerants are already commercially available to a certain degree (e.g. chillers, commercial and industrial heat pumps), or are expected to become available very soon (e.g. residential heat pump water heaters, room AC), could be accelerated through legislation (SNAP approval, UL review) as well as incentives for end users.

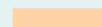
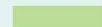
For mainstream applications where natural refrigerant-based equipment is already commercialized or is likely to be in the near future (industrial, commercial and light commercial refrigeration), detailed analysis is provided for the role each refrigerant will play in this growth. These sectors are further explored in their own individual chapter as part of the "key applications" section of this publication. For other applications, brief commentary has been added on the developments that will add to their momentum.

The following colors indicate the current and anticipated level of commercial availability in the U.S.:

Wide commercial availability = several suppliers and sufficient production capacities

Semi-commercial availability = few suppliers, low-volume production

Not commercially available yet = technology in R&D or demonstration phase



REFRIGERATION	2015 - 2020		2020 - 2025		2025 - 2030
DOMESTIC		2016			
LIGHT COMMERCIAL (PLUG-IN)		2017			
COMMERCIAL		2017			
INDUSTRIAL					
ROAD TRANSPORT		2018		2022	
AIR CONDITIONING	2015 - 2020		2020 - 2025		2025 - 2030
SMALL ROOM A/C (SELF-CONTAINED)		2016			
MULTI-SPLIT / VRF A/C					
CHILLERS		2017			
RESIDENTIAL HEAT PUMPS FOR WATER HEATING		2017			
RESIDENTIAL HEAT PUMPS FOR SPACE HEATING AND COOLING					
COMMERCIAL AND INDUSTRIAL HEAT PUMPS					
MOBILE AIR CONDITIONING					

Industrial refrigeration: natural refrigerants already mainstream

CO₂ GROWTH POTENTIAL



The use of CO₂ in industrial refrigeration in both transcritical applications and cascade systems is a recent trend that has emerged in the phaseout of R22. While low-charge ammonia currently is the most obvious trend, the increasing use of CO₂ in various applications ranging from ice rinks to distribution centers shows that its growth will continue, but to what extent is debatable.

NH₃ GROWTH POTENTIAL



By 2020, the use of R22 will be completely outlawed, with ammonia being the clear heir to the throne. The use of low-charge ammonia systems is the most populous solution in North America and there are also a healthy number of NH₃/CO₂ cascade systems. These “next-generation” solutions will be added to the already large amount of ammonia systems – estimated to have 90% of the market – used for large refrigeration applications in the U.S.

HYDROCARBONS GROWTH POTENTIAL



The use of R1270 as a primary refrigerant has been reported once across North America and as such remains a niche choice, but it does have its own advantages such as ease of maintenance. However, it is not likely to appeal to the mass-market. Although, the use of hydrocarbons in industrial applications will appeal to the petrol industry where it is an efficient solution.

Commercial refrigeration: strong growth expected in next two years

CO₂ GROWTH POTENTIAL



In commercial refrigeration, CO₂ is a potential market leader. Recent data indicates that the U.S. CO₂ market is expected to grow to roughly 100 times its current size. In northern U.S. states and in Canada, CO₂ transcritical is increasingly becoming a standard for retailers such as Sobeys. However, in high-ambient temperatures, there is still development on-going that come mean the CO₂ transcritical takeoff for the entire U.S. may be delayed. However, even in high-ambient temperatures, there is interest in NH₃/CO₂ cascade systems, suggesting that CO₂ will have a clear place in the south as well as the north.

NH₃ GROWTH POTENTIAL



In high-ambient temperatures, there is an increasing use of NH₃/CO₂ cascade systems in commercial refrigeration, though not to the level of transcritical in the northern regions. As such NH₃/CO₂ will remain a good choice for retailers looking to improve energy efficiency and reduce carbon emissions in their retail stores, but is unlikely to become a continent-wide trend.

HYDROCARBONS GROWTH POTENTIAL



The use of hydrocarbons in a micro-distributed system is another option for deploying natural refrigerants in the retail industry. The propane charge limit for these retail units is maximum 150 grams per circuit, meaning its application is at present fairly limited. Nevertheless some U.S. retailers have shown their preference for such systems, which can achieve substantial energy savings in the southern U.S. states.

Light Commercial Refrigeration: CO₂ and HC to become a standard by 2030

CO₂ GROWTH POTENTIAL



The number of placements of CO₂-based light commercial refrigeration equipment shows that it is a clear area for growth in North America. While the use of CO₂ may not be dominant in the whole of the sector – with hydrocarbons being used more often in freezers – it is an area that will certainly continue to grow greatly as energy requirements take a hold of the market.

HYDROCARBONS GROWTH POTENTIAL



The figures don't lie; there has been a massive market uptake in the use of hydrocarbons in light commercial refrigeration in both drink coolers and freezers. With the potential to be used in ice machines to help companies meet upcoming energy efficiency standards, the certainty of hydrocarbons in the future of light commercial refrigeration is undisputed.

Applications on the horizon

DOMESTIC REFRIGERATION WILL SLOT INTO PLACE SOON

Following the successful EPA approval of the use of propane in domestic refrigeration in June 2014, the commercialization of this application is expected to happen sooner rather than later with a huge array of experience in using this equipment in Europe and Asia where it is a standard. The U.S. market is taking slightly longer to adopt than first anticipated, which is partly due to the restrictive standards allowing only 56 grams of hydrocarbons in a single refrigeration circuit (compared to 150 grams in Europe). Once adopted, hydrocarbon-based domestic refrigeration will not only dramatically reduce CO₂ equivalent emissions, it will also improve energy efficiency between 30% and 60% compared to traditional HFC units.

ON THE ROAD AGAIN: CO₂ TRANSPORT REFRIGERATION MOVES FORWARD

Since the last GUIDE to North America was published in 2013, there has been a gentle acceleration in the development of CO₂ transport refrigeration. After the successful SNAP approval given by the EPA for the use of CO₂ in transport refrigeration, the industry is gearing up for the implementation of CO₂-based solutions. One of the major manufacturers of refrigerated transport equipment has plans for commercializing its CO₂-based technology in the U.S. by 2020. With this development in mind, industry experts anticipate a larger commercial availability of such equipment by 2022.

CO₂ DOMESTIC HEAT PUMPS BEGIN TO JACK UP MOMENTUM

CO₂-based heat pumps have become a standard technology for water heating in Japan, but are increasingly becoming popular in other regions, such as Australia and Europe. Developments are underway in the U.S. as well with several manufacturers of CO₂ heat pumps having indicated that they plan to start commercialization of their products in the region within the next 1-2 years. CO₂ is not yet approved for use in heat pump water heaters under the SNAP Program and the process of commercialization will depend on alleviating this legislative obstacle. In addition,

new products will have to undergo a certification process and their acceptability by end consumers will play a role in accelerating their commercialization. Meanwhile, the development of natural refrigerant-based heat pumps for space heating and cooling is currently ongoing and will require further R&D in order to reach higher energy efficiency. The industry expects to commercialize its first products in the North American market a few years after the introduction of heat pumps for water heating.

INCENTIVES COULD BE KEY TO ACCELERATING COMMERCIALIZATION OF LARGER HEAT PUMPS WITH NATURAL REFRIGERANTS

A number of companies already offer CO₂ and ammonia-based heat pumps for commercial and industrial use in the North American market, or have plans to launch such products in the near future. The industry believes that scaling up the commercial availability of large natural refrigerant heat pumps will greatly depend on legislative signals favoring such technology as opposed to HFC-based systems. Given that this technology achieves very promising energy performance, energy efficiency incentives could speed up the introduction of the technology.

SINGLE SPLIT AC REQUIRES LEGISLATIVE REVIEW

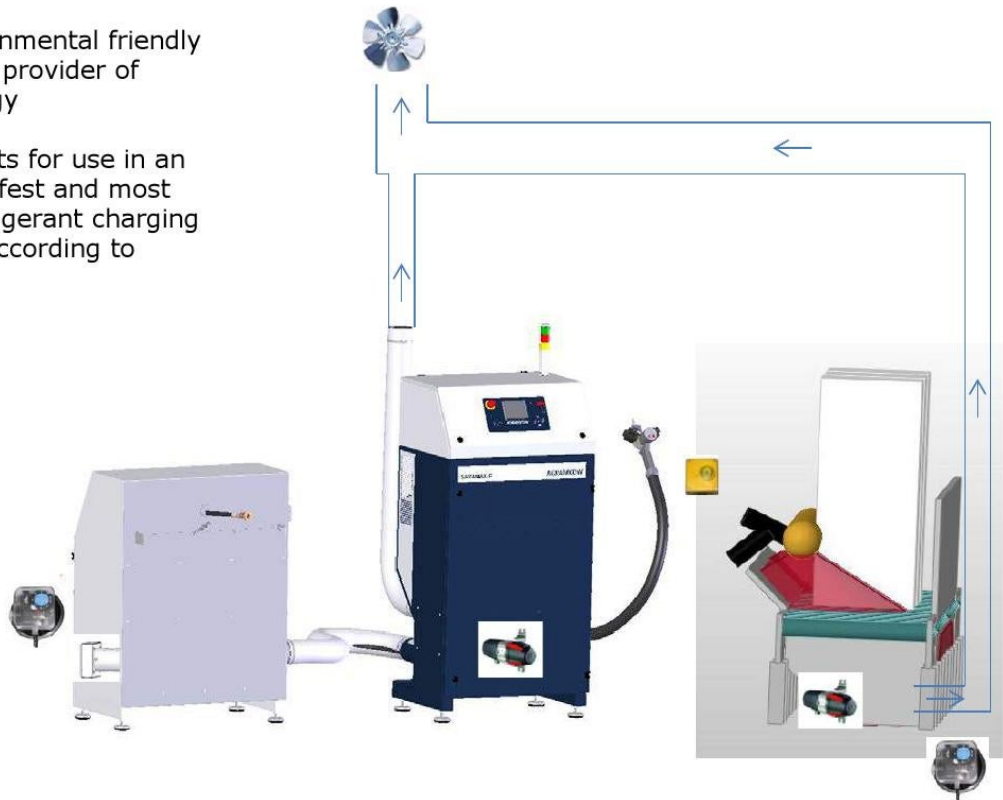
Hydrocarbons R290 and R441A are approved (subject to use conditions) for use in residential and light commercial air conditioning. Given the global trends in the shift to R290 in room AC applications, as well as the foreseen conversion of 20 room AC manufacturing lines to R290 in China, the introduction of such systems in the U.S. could happen relatively swiftly (China manufactures 85% of global RAC production.) Nevertheless, the recently revised UL 484, which limits the R290 refrigerant charge to 114 grams, is currently a major obstacle to adoption of hydrocarbon-based room air conditioners in the U.S. Full commercial availability of natural refrigerant-based equipment in this sector can only be expected if the UL standard is reviewed to allow higher refrigerant charges for flammable refrigerants.

SARAMAX F Charging station

for HC production lines (R290 and R600a)

Meet the challenge for the new environmental friendly refrigerants together with the leading provider of Hydrocarbon manufacturing technology

This system meets all the requirements for use in an explosion proof area, providing the safest and most flexible solution to a hydrocarbon refrigerant charging process – Class 1, Div 2 compliancy according to NFPA, UL, IBC, IFC



Future policy trends in North America

EPA DELISTING LOOKS TO REDUCE GWP IN COMMERCIAL REFRIGERATION

As mentioned in the “North America Today” chapter, the U.S. EPA is not just responsible for evaluating and allowing the use of refrigerants for individual applications, they are also able to change the status of already approved refrigerants, making them “unacceptable” for use in new or retrofitted applications.

The recent SNAP Final Rule published in July introduces a ban (by a certain year in the future) on the use of certain high-GWP refrigerants, such as R134A, R404A, R507 and others, especially in commercial and light commercial applications.

This administrative action, which caused a lot of discussion in the industry, is expected to have a large impact on the affected applications.

In a discussion preceding the publication of the Final Rule, industry experts evaluated the potential full commercial availability of natural refrigerant-based equipment in the commercial refrigeration sector. Results indicate that the industry will be ready to meet the EPA SNAP requirements through introduction of natural refrigerants in the 2016-2020 timeframe.

CANADA CONSIDERS HFC MEASURES IN LINE WITH U.S.

With a view of aligning with the legislative action on HFCs taken by the U.S. EPA, Canada announced its intent to regulate HFCs in September 2014. Following this announcement, Environment Canada has taken the initiative in putting forward possible approaches for discussion, which include prohibitions on specific HFCs by specific years (depending on the sector) and a gradual phasedown of HFCs.

In a consultation document that collected input from the industry in February-March 2015, it is suggested that a sector-specific prohibition on certain high-GWP HFCs are introduced as of 2017 in new and retrofit commercial refrigeration applications, including direct and indirect supermarket systems, condensing units, vending machines and stand-alone equipment.

A gradual phasedown of HFCs, considered as a possible second option, would be modeled after the proposed amendment to the Montreal Protocol put forward by North American countries. A first reduction of 10% (compared to a baseline calculated as average HFC and HCFC consumption and production in 2008-2010) could come into force in 2018. The government has indicated that a combination of both approaches (HFC bans & HFC phasedown) could also be taken as a way forward. After collecting industry feedback, the government is currently working on these measures, which should become known later in 2015.

Application / type of equipment	HFCs listed as unacceptable	New equipment	Retrofits	Natural refrigerants approved under SNAP
Vending machines	R134a, R507, R404A and other high-GWP HFCs	as of Jan 1, 2019	1 year from publication of the final rule in the federal register	CO₂, R290a, R441A, R600a
Supermarket systems	R404A, R507A and other high-GWP HFCs	as of Jan 1, 2017	1 year from publication of the final rule in the federal register	CO₂, NH₃ vapor compression with secondary loop
Remote condensing units (supermarkets)	R404A, R507A and other high-GWP HFCs	as of Jan 1, 2018	1 year from publication of the final rule in the federal register	CO₂
Stand-alone units	R404A, R410A, R134a, R407F and other high-GWP HFCs	as of Jan 1, 2019 or Jan 1, 2020 (depending on compressor capacity)	1 year from publication of the final rule in the federal register (only applicable for R404A, R507A)	CO₂, R290, R600a, R441A
Mobile air conditioning	R134a	as of model year 2021 (except where allowed under a narrowed use limit through model year 2025)	N/A	CO₂

EPA SNAP delisting furthers the case for natural refrigerants

At the beginning of July 2015, the EPA announced the delisting of the use of R134A, R404A, R507A and other high-GWP HFCs in several major applications as of 2017 or later. While the initial proposal indicated that the market might delist these fluorinated gases as early as 2016, ultimately this was not the case and there is instead a staggered delisting, giving companies ample time to make the switch to naturals. Each application that has delisted HFCs also has approval for the use of natural refrigerants, so there is the case that companies can make the direct switch to these with new machinery.



Industry viewpoint

ON DELISTINGS...

Quentin Crowe –

Associate Product Manager, Hussman Corporation

I believe this is going to encourage some large retailers using R404A to consider transcritical CO₂ in applications where it can be proven financially feasible in northern regions. This increased volume will help drive cost effective solutions so that transcritical CO₂ can look more attractive in southern climates over the next couple years. I don't think it would be in anyone's benefit to do it sooner than decided, as there still needs to be training and design improvements to optimize equipment for these new lower-GWP refrigerants.

Parker Sporlan team

We don't think it will materially change it [the demand for adoption of CO₂ transcritical systems in retail food refrigeration]. There have been other options to R404A and R507 for years (R407A, C, and F), and the EPA's companion rule approving R448A, R449A, and R513A gives the industry more choices. We feel the adoption of CO₂ stores overall will continue to increase, including transcritical systems, but will be more driven by technology and economics.

Charlie Hon –

Engineering Manager, True Manufacturing

We believe the sector most affected will be self-contained refrigeration. There will be fewer options available for this sector so natural refrigerants will tend to be selected more than other options. There is still a chance that more HFO products will be available before the deadline. Some companies may choose to go in that direction. The biggest question will be, is system efficiency able to meet the 2017 DOE standards?

Harrison Horning –

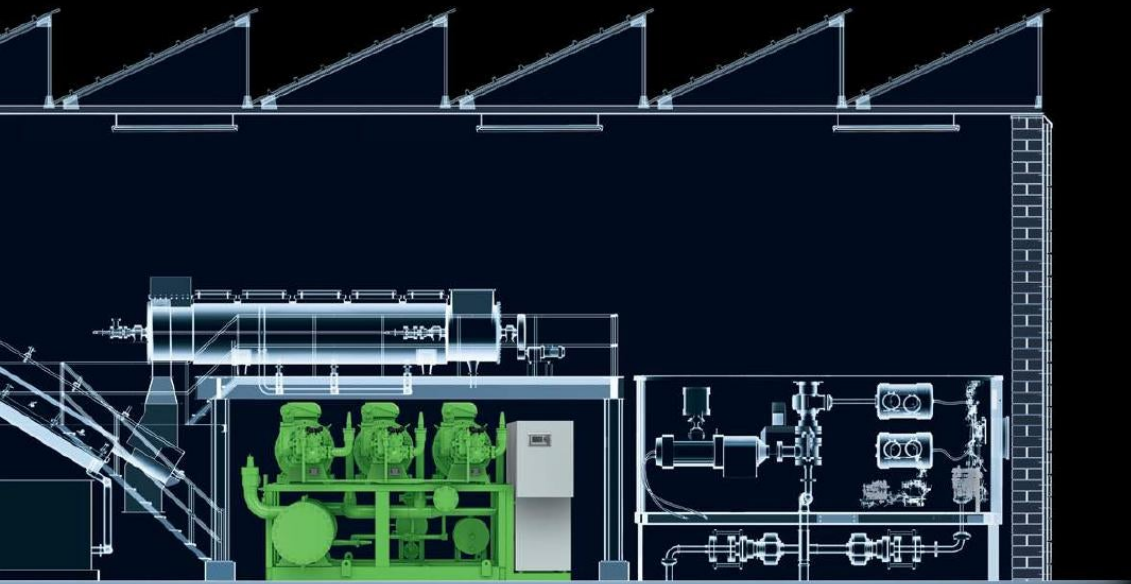
Director of Energy and Facilities, Hannaford Supermarkets

I think the industry will have ample time to adjust to the delisting of R404A and R507A in central systems. But global experience is showing that stand-alone units can have very small charges and very tight systems, which suggests certain HFCs (R134a, R410A) could be applied with very low greenhouse gas emissions.

Gerald Wozniak –

Environmental Engineer, SNAP Program, Environmental Protection Agency

There will be more delistings as well as approvals.



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WE HAVE THE NEW AMMONIA COMPRESSOR PACK FOR YOU!

The new Ammonia Compressor Pack (ACP) from BITZER promises high efficiency at full- and part-load operation with strong reliability, even in complex industrial refrigeration and process cooling applications. The modular design of the ACP combines two or three compressors, a common oil separator, and a frequency inverter to provide a broad range of operation in high temp, mid temp or low temp applications. The ACP also features additional highlights such as compressor and controls redundancy as well as service friendliness. Learn more about our products at www.bitzerus.com



THE HEART OF FRESHNESS

Key applications for natural refrigerants in North America

Introduction

The following chapter gives an in-depth analysis of the three sectors that are outstanding in their adoption of natural refrigerants in North America. The light commercial, commercial and industrial refrigeration sectors have all developed greatly since the last GUIDE to North America published in 2013 and remain the most immediate sectors for a potential mass adoption of natural refrigerants.

The chapter highlights the growth experienced in the last two years, providing detailed data maps specifying the location of installations and equipment for all three sectors. In addition, the chapter highlights any progress in natural refrigerant-friendly policy that allows for a greater role for natural refrigerant-based equipment. The chapter also outlines potential market, technological and policy trends for the future in light commercial, commercial and industrial refrigeration through the use of the GUIDE survey and the Industry Viewpoint section, which collects the findings of experts in the HVAC&R industry.

While highlighting these leaps forward by each market, the chapter also serve as an opportunity to highlight areas that can be improved in terms of market uptake and policy, using other regions as examples of best practices.





Light commercial refrigeration

Introduction

The light commercial refrigeration market is one of the most exciting sectors in North America as large multinational consumer brands are the key drivers for the uptake of natural refrigerants. With big budgets and global plans, there is a different feel to the future of this market that has more than one natural refrigerant in its ascendency.

The Coca-Cola Company, one of the world's most valuable brand, promotes the use of CO₂ in their drinks cooling equipment, while other global brands such as Red Bull and Unilever prefer the use of hydrocarbons for their light commercial refrigeration equipment. While hydrocarbons have been safely used in many other world regions for nearly 15 years, their flammability is still a concern for some companies. The U.S. EPA SNAP approval of more hydrocarbons and the delisting of many high-GWP HFCs means that this sector is perfectly poised and will be one to keep an eye on for both manufacturers and consumer brands.

In the last GUIDE to North America in 2013, the total amount of light commercial equipment was closer to 5,000 units but now it stands, conservatively, at over 291,000. It is clear that the market is developing, with signs that this will be greatly accelerated in the near future as a result of key policy changes, including the requirement for improved efficiency in 2017 imposed by the U.S. Department of Energy. Light commercial refrigeration is also where Mexico is most visible in its use of natural refrigerants, preferring to use hydrocarbons that work efficiently in high-ambient temperatures.

Over 291,000 natural refrigerant-based light commercial units currently in North America

Over 181,000 of light commercial equipment using hydrocarbons and 109,000 using CO₂ in North America

MEXICO LEADS THE WAY IN USE OF NATURAL REFRIGERANTS IN LIGHT COMMERCIAL REFRIGERATION



MEXICO

188,371

29,064

CO₂

159,307

HC



U.S.

94,493

77,000

CO₂

17,493

HC



CANADA

8,172

3,797

CO₂

4,375

HC

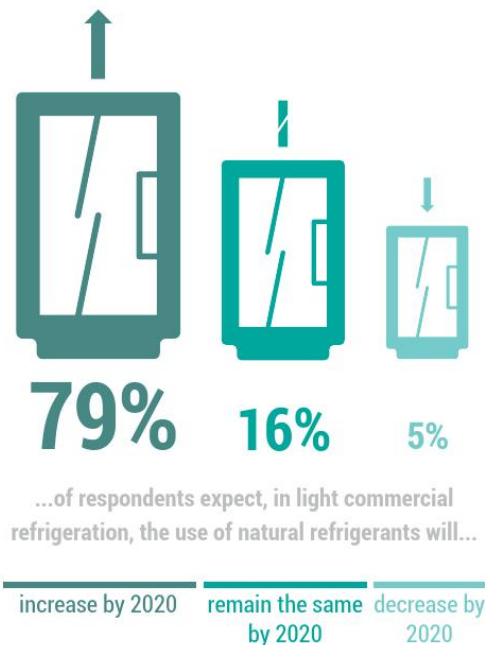
MEXICO: A HAVEN FOR NATURAL REFRIGERANTS IN LIGHT COMMERCIAL REFRIGERATION

In shecco's data analysis, there was a clear trend towards an accelerated implementation of natural refrigerants in Mexico. The particular success Mexico has enjoyed with regards to hydrocarbons, especially in light commercial refrigeration, can be attributed to several factors.

First, the policy climate is primed for change due to Mexico's concrete HCFC phase-down plans. Mexico has adopted a number of policies to control consumption of HCFCs. By putting in place a "general law of climate change," Mexico has created an institutional framework with the following five stages: planning, finance, instruments, assessment and law enforcement. Also, in terms of HCFC management, the special program for climate change for 2013-2018 aims to control the emissions of high-GWP refrigerants by promoting HFC replacement projects, while, in parallel, supporting the development of demonstration projects for both the domestic and commercial refrigeration sectors, as well as commercial air conditioners.

In Mexico's HCFC phase-down management plan, domestic and commercial refrigeration are the focus of the first stage along with the aerosol, foam and servicing sectors. The second stage, which seeks to phaseout 67.5% of HCFCs, has an end objective of making hydrocarbons a standard technology in refrigeration. The promotion of Mexican firms working with hydrocarbons has also encouraged the market and currently there is one refrigeration company producing domestic refrigeration with hydrocarbons and two commercial refrigeration companies producing stand-alone units with hydrocarbons and CO₂.

But it is not just the agreeable policy climate that is pushing light commercial equipment; it is hydrocarbons's efficiency as a refrigerant. While shecco's data shows that Mexico also has CO₂ stand-alone units, the vast majority use hydrocarbons as they perform well even in high-ambient temperatures. The lack of efficiency compromises, its encouraging policy and its positive contribution to their HCFC phaseout has made Mexico's light commercial sector one of the most prosperous in the last two years.



Light commercial refrigeration on the up for naturals

Only 5% of respondents believe the use of natural refrigerants will decrease by 2020 and 16% believe the use will remain the same. But the remaining 79% see the use of natural refrigerants in the light commercial sector increasing by 2020. This is reflective of what seems to be an inevitable takeover of the sector once fluorinated gases become unsustainable.

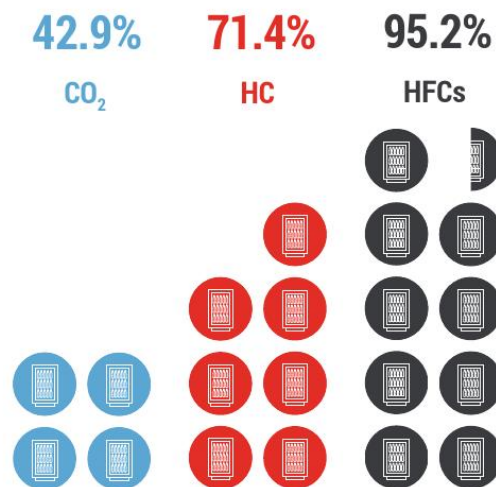
MAJOR MANUFACTURERS MAKING THE SWITCH TO NATURAL REFRIGERANT-BASED EQUIPMENT

With the EPA's recent delisting of high-GWP HFCs, many manufacturers are already looking at how best to accommodate the switch. This message was similarly echoed in the industry survey, which saw over 50% of respondents intend to use natural refrigerants in the future in the light commercial refrigeration sector. It has been remarked that the HVAC&R is a slow market in terms of change, so the acceleration of long-term plans shows the earnestness of a sector that is facing changes that are non-negotiable.

This switch is having a clear impact on price. For instance, in 2004, the cost of CO₂ equipment was double the price of the fluorinated gas equivalent, but now the cost differential has narrowed substantially and, in some instances, it is cheaper to purchase CO₂-based equipment. It has been posited that the surge in use of natural refrigerants by major consumer brands has led to the decrease in price. This is, of course, not taking into account the steep increase in price that fluorinated gases are likely to experience in the event of further restrictions, as supply dwindles.

It is not just the decline in cost that has come from years of use, but the improvements in the components inside. The Coca-Cola Company has said that between 2004 and today, the CO₂ compressor has lost between 4.4 and 6.6 pounds of steel. They believe that this change will extend to heat exchangers, coils and other components, lowering the cost even more.

This can be seen by the increased demand for coils that are tailored for use with CO₂, R290 and R600. For coils using hydrocarbons, a major driver is refrigerant charge minimization, which creates a demand for small-diameter tubes and compact coil surfaces. With heat exchangers, innovation is also ongoing to meet anticipated demand and comply with the forthcoming regulatory framework.



CO₂ and hydrocarbons are speeding up but companies are still utilizing HFCs in light commercial sector

The use of CO₂ and hydrocarbons is picking up pace in light commercial refrigeration but it still must contend with the use of HFCs within the market as nearly 100% of those involved in this sector noted that they use HFCs. The phasing-out of HFCs in stand alone units by large consumer brands is an ongoing process and many consumer brands have objectives for an HFC-free fleet by 2020. So this market will continue to become natural even if the present situation still features fluorinated gases.

GLOBAL CONSUMER BRANDS DRIVING NATURAL REFRIGERANT ADOPTION IN LIGHT COMMERCIAL SECTOR

Unlike other application areas, there is a sense of glitz and glamor to the use of natural refrigerants in the light commercial refrigeration sector as brand names continue to show their growing commitment to sustainability. North America is a huge part of a global strategy that has seen companies populate the earth with natural refrigerated light commercial equipment. With three of the five countries that consume the most carbonated drinks per capita in the world, the scope for placements of light commercial refrigeration equipment in North America is justifiably large.

The replacement of HFCs with natural refrigerants in millions of glass-door merchandisers is one of the most direct ways to achieve an improved carbon footprint for companies as point of sales equipment accounts for up to one-third of a company's carbon footprint. It is also seen as low-hanging fruit, as not only is it in line with a more global understanding of the negative effects fluorinated gases bestow upon the environment; the use of natural refrigerants also improves energy efficiency, with up to 45% energy savings quoted by major consumer brands.

With environmental friendliness and increased energy efficiency making the case for natural refrigerants, two natural refrigerants have come to the forefront to be the substance of choice for global consumer brands in their light commercial refrigeration equipment. The use of CO₂ can be seen in the Coca-Cola Company's

global campaign to reduce the footprint of "the drink in your hand". When discussing their choice of CO₂ as a refrigerant, Coca-Cola has mentioned their early experimentation with hydrocarbons, eventually deciding against its use, as it did not serve the purpose of Coke's global strategy, linked to global procurement and cultural perceptions in certain countries. In addition to this, technology-wise Coca-Cola has noted that even if it used hydrocarbons, it need CO₂ anyway due to the larger size of some of its equipment.

However, other companies such as Red Bull and Unilever extol the virtues of hydrocarbons. Their energy efficiency properties are well documented, especially in warmer climates. The decision to choose hydrocarbons or CO₂ will affect more and more companies as they make the switch in light of upcoming legislative deadlines.

A side effect of the use of two different refrigerants is the impact on training. Consumer brands have had little problem in training their engineers to handle the equipment, noting that the training for hydrocarbons and CO₂ is based on knowledge of conventional systems. This is encouraging for other markets as it shows that with time, perceived entry barriers such as higher initial costs and training requirements can be surmounted, allowing the market to flourish.



Reduce the carbon footprint of “the drink in your hand” by 25% by 2020.

“We are reaching an inflection point in our HFC-free global system adoption. We are at the phase where CO₂ is the technology that fits our portfolio of equipment.”

Founded: 1886

Headquarters: ATLANTA, USA

Global fleet that uses natural refrigerants: 1.5 MILLION UNITS

Placements in North America: 12,354

CO₂



Cut the environmental footprint of making and using its products by 50% by 2020

“Nearly 2 million cabinets [with hydrocarbons] running all over the globe, which is ahead of formal targets. In the United States, hydrocarbons were prohibited and Unilever succeeded in gaining formal approval.”

Founded: 1929

Headquarters: ROTTERDAM, NETHERLANDS & LONDON, UK

Global fleet that uses natural refrigerants: 2 MILLION UNITS

Placements in North America: 133,245

HC



Complete 100% global procurement of hydrocarbon eco-coolers

“As early adopters of this technology, we have seen a significant decrease in energy usage. Less harm to the planet while increasing profit to our accounts’ business is clearly a win/win. Our hope is that as our use of this technology grows, the overall light-commercial refrigeration market will convert with us.”

Founded: 1987

Headquarters: FUSCHL AM SEE, AUSTRIA

Global fleet that uses natural refrigerants: > 500,000W UNITS

Placements in North America: 59,948

HC



PEPSICO

All point-of-sale equipment to be HFC-free by 2020.

“I believe all of us need to take action now. PepsiCo has already taken actions in our operations and throughout our supply chain to ‘future-proof’ our company—all of which deliver real cost savings, mitigate risk, protect our license to operate, and create resilience in our supply chain.”

Founded: 1898

Headquarters: NEW YORK, USA

Global fleet that uses natural refrigerants: 240,000 UNITS

Placements in North America: N/A

HC

CO₂



WOULD YOU LIKE SUSTAINABILITY WITH THAT? MCDONALD'S AND STARBUCKS LOOK TO INTEGRATE HYDROCARBONS INTO THEIR EQUIPMENT

It is not just the point-of-sale cabinets in supermarkets that are to seeing an upheaval in their equipment and company branding. Food service companies are also looking to join the fight. McDonald's especially, following its European exploits, is looking at ways to accelerate the uptake of naturals in the insert U.S. market.

This has been facilitated by regulations that will increasingly see the presence of natural refrigerants become a stark reality. We can see in other regions that the use of natural refrigerants is possible in various appliances commonly used in commercial kitchens and restaurants. The general policy and market tides are moving this trend forward in the North American market.

Other companies such as Starbucks are investigating the role natural refrigerants can play in their operations. Starbucks has begun trialing the use of R290-based refrigeration units in its coffee shops. As a franchise, McDonalds has noted that in terms of co-ordination, this type of mass installation will take time. But with the approval of R290 in March 2015, this option has created interest in the food service industry. If big brands can drive installation and as a result lower the price for hydrocarbon based-equipment, creating a second brand revolution involving natural refrigerants in the light commercial refrigeration sector.



Current status: Trialing equipment in the U.S.

"Natural refrigerants make business sense and it's the right thing to do for the environment."

Founded: 1940

Headquarters: ILLINOIS, U.S.

Global fleet that uses natural refrigerants: >11,000 UNITS

Placements in North America: N/A

HC



Current status: R&D and testing

"Rapid growth in the 2000s are leading to the end of life of a significant number of units and the 2014 EPA ruling on naturals enabled suppliers to tool up for supply and support of natural refrigerants."

Founded: 1971

Headquarters: SEATTLE, WA

Global fleet that uses natural refrigerants: N/A

Placements in North America: N/A

HC





Industry expects swift transition to naturals in light commercial refrigeration

As can be seen from the live polling at ATMOsphere America 2015 during a light commercial-based session which had key stakeholders attending, over 90% of attendees believe that natural refrigerant-based light commercial refrigeration equipment will become fully commercially available soon, with 2018 seen as the latest possibility and only 8% thinking it will be later than 2018.

Policy drivers for natural refrigerants in light commercial refrigeration

US EPA SNAP APPROVALS ACCELERATE MARKET UPTAKE OF HYDROCARBONS AND CO₂

On February 27, 2015, EPA Administrator Gina McCarthy signed a final rule listing additional hydrocarbon refrigerants as acceptable substitutes for HCFCs under the Significant New Alternatives Policy (SNAP) Program in certain refrigeration and AC applications, having a direct bearing on the light commercial refrigeration market. The following hydrocarbons were approved in:

- » Stand-alone commercial refrigerators and freezers – R600a, R441A
- » Vending machines – R600a, R290 and R441A

The ruling represents a major shift in perception towards hydrocarbons in the U.S. since the EPA's first approval of R290, R600a and R441A in retail and domestic refrigeration in 2011. The original listing in 2011 took over two years to approve while the latest SNAP ruling took just eight months to push through, signifying growing market confidence towards hydrocarbons as a viable alternative to high-GWP refrigerants.

In addition, the final action exempts the hydrocarbon refrigerants from the Clean Air Act's prohibition on venting, release or disposal, in specific end-uses for which they are now listed, on the basis of current evidence that they do not pose a threat to the environment. In the first round of hydrocarbon approvals, the venting prohibition was lifted two-and-a-half years later.

The approval of hydrocarbons in stand-alone refrigeration and vending machines has contributed to the full spectrum of natural refrigerants that are allowed to be used in light commercial refrigeration. CO₂ has been on the market in this sector for a few years now, after receiving a green light from the EPA in 2009 for use in food retail refrigeration and in 2012 as the first natural refrigerant allowed in vending machines.

VOLUNTARY ACTION FROM INDUSTRY SHOWS THIS IS A DESIRABLE MOVE

In September 2014, United States President Barack Obama announced a series of moves aimed at cutting emissions of hydrofluorocarbons, including securing voluntary agreements with PepsiCo, Coca-Cola and Red Bull to reduce their use and replace them with climate friendly alternatives.

This is a huge commitment from the private sector and opens the way for other like-minded companies to follow in their footsteps. These consumer brands' corporate commitments alongside other companies could lead to the equivalent of 700 million metric tons of CO₂ being eliminated through to 2025, equal to 1.5% of the world's 2010 greenhouse gas emissions.

The light commercial refrigeration sector shows more than any other sector that corporate responsibility in North America could be the driver that curtails a huge percentage of greenhouse gas emissions through the switch to natural refrigerants. Another example of voluntary collective action is the formation of the group Refrigerants, Naturally!, a group comprised of four of the biggest global consumer brands: Red Bull, Pepsico, Unilever and Coca-Cola. Refrigerants, Naturally! advocate the replacement of HFCs by natural refrigerants. The global non-profit initiative also has the support of Greenpeace and the United Nations Environment Program (UNEP).

DELISTING OF HIGH-GWP HFCS SPURS ON UPTAKE OF NATURAL REFRIGERANT TECHNOLOGY

Besides approving new refrigerants, the EPA has the authority to withdraw substances from the list under the SNAP Program, which effectively means such substances would no longer be permitted for use in specific applications. The original

proposal was for the delisting of certain high-GWP HFCs, including R134a, in new stand-alone retail refrigeration and vending machines as soon as in 2016.

While the actual date imposed ended up being 2019 and 2020 for stand-alone units (depending on compressor capacity) and 2019 for vending machines, there is still a clear indication that the government wants to get rid of high-GWP gases, including R134a in light commercial refrigeration. This legislative signal is already creating a lot of movement in the industry and an increasing number of end users see natural refrigerants as a future-proof solution.

INCOMING DOE STANDARDS FOR 2017 AND 2018 TARGET ICE MAKERS AND STAND-ALONE UNITS

The DOE's new energy efficiency standards for upright glass-door freezers, horizontal ice cream freezers, and bottle coolers are one of the most important drivers towards natural refrigerants, especially hydrocarbons due to their energy performance in these applications. The proposed standards pose a weighty challenge for system manufacturers. For example, the new standards could require 57% less energy consumption for an upright glass-door freezer. With these increasing requirements, it has been noted that to achieve these levels of efficiency, companies would likely have to switch to naturals.

Updated energy conservation standards for automatic commercial ice makers are likely to increase the demand for natural refrigerants further still. It needs to be noted, though, that neither CO₂ nor hydrocarbons have been approved for use in this application yet under the EPA SNAP Program. Also, by law the DOE has to re-evaluate its standards every five years, with the potential to have this cut down to every three years. The agency may reduce this window to every three years, which would enable it to react faster to unforeseen circumstances.



Industry viewpoint

ON MOTIVATION TO ADOPT NATURAL REFRIGERANTS...

Paige Dunn –

Head of CSR and Sustainability, Red Bull

We have found that this technology is the best solution for both us and for our accounts. As early adopters of this technology, we have seen a significant decrease in energy usage. Less harm to the planet while increasing profit to our accounts' business is clearly a win/win. Our hope is that as our use of this technology grows, the overall light-commercial refrigeration market will convert with us. Hydrocarbon coolers are not the future; they are by far some of the most premium products on the market now.

Tomas Ambrosetti –

Global Program Director of the eKOfreshment Program, The Coca-Cola Company

We're implementing a technology that's not easy, that puts a lot of pressure on the system. But I absolutely believe that what we're trying to do here potentially leaves the world in a better place than we found it. I think there's a social responsibility to doing some of this. I have a lot of passion for what I do.

Antoine Azar –

Global Program Director, The Coca-Cola Company

I am confident that CO₂ is the future, for our applications at least. CO₂ is the only technology that has the safety, coverage, performance and cost we are looking for. We made the right bet.

Mike Weisser –

Vice President of Sales and Marketing, Sandenvendo America

There's a big opportunity for natural refrigerants, particularly CO₂, to play a role in the light commercial market.

Andres Martinez-Negrete –

Technical and Product Development Manager, Imbera Cooling

We are confident that more people will start choosing natural refrigerants in the next five years – two or three times what we have at his point.

ON BARRIERS...

Roy Buchert –
Worldwide Energy Director, McDonald's

The biggest obstacle to deployment of natural-refrigerant systems at McDonald's more than 14,267 U.S. restaurants – almost 40% of its worldwide total, generating about one-third of its global revenues – is the lack of a service infrastructure able to maintain the equipment. Until we get a good answer to that, the deployment [of natural-refrigerant equipment] in the U.S. will not likely be as significant as it could be.

Bruce Karas –
Vice President of Environment and Sustainability, Coca-Cola North America

Regulators need to be aware of the virtues of natural refrigerants but also the implementation, something that regulators sometimes aren't aware of.

ON REGULATIONS...

Tomas Ambrosetti –
Global Program Director of the eKOfreshment Program, The Coca-Cola Company

We appreciate what the EPA is trying to do – trying to phase out R134a. We think it's accelerated the conversation. There's a lot of pressure now on our OEMs and us to move in that direction. The flip side to that is if you're not ready, you can run into some trouble. It may generate significant costs in the system; there's a lot of angst about what that might do to your business. So we're highly supportive of what the EPA is trying to do but we need help to be commercially viable in getting there. That's the feedback we're providing to the EPA.

Rajan Rajendran –
Vice President of System Innovation Center and Sustainability, Emerson

R404A is the worst offender that we have right now and unfortunately we are still using it in huge amounts. So if you're sitting with R404A or R134a, then life is going to change. It is already happening in Europe and there is a very high likelihood that it is going to change for us in the U.S. once the summer has come.



Energy efficient propane plug-in cabinets in discount retail stores

INTRODUCTION

Energy costs are high in Germany and in most other European countries, whereas sales margins in food retail are traditionally low. As a response to this situation, a system manufacturing company was approached by the market-leading grocery chains to supply a self-contained display cabinet that possesses higher efficiency than existing cabinets, to help improve margins. According to studies, refrigeration in standard grocery stores contribute 55% to the use of primary energy, so to have a high-efficiency refrigeration system was of the utmost importance for discount retail chains.

The system manufacturer teamed up with Secop – Danfoss Compressors at the time – as one of their main compressor suppliers to work on a cabinet according to the specifications given by the commercial end users. The product was a success and is now being adapted for the North American markets.

ABOUT THE SYSTEM

Self-contained display cabinets are very common among European discount food retailers as restricted floor spaces do not favor large centralized installations. The single plug-in cabinets can be quickly rearranged if standing alone or installed in an island setup to be accessed by the customers from both sides. They usually contain frozen and low-temperature chilled food, rather than dairy products.

As well as improved energy efficiency, the cabinets also required additional functions for their daily operation, including:

Vist for more information

www.secop.com

SECOP

Contact information

Pieter Boink

p.boink@secop.com

+49 461 4941 730

ABOUT THE COMPANY

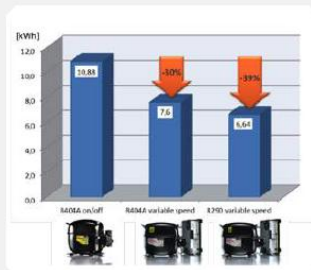
Secop is a German supplier of hermetic refrigeration compressors for domestic and light commercial appliances with a focus on systems using hydrocarbons as a refrigerant. Secop cooperated with a system manufacturing company to develop a plug-in display cabinet to help significantly reduce energy costs for discount food retail chains.

- » Hazard analysis and critical control point
- » Alarm to signal failures at set temperatures
- » Remote monitoring of temperatures and consumption levels
- » Automatic defrost to prevent accumulation of ice that increases energy consumption due to insulation effects
- » Control of lighting

To reduce energy consumption of the refrigeration cycle, Secop proposed to use an electronically controlled compressor that is able to adjust its rotating speed and therefore the cooling capacity. Secop's experiences with variable speed compressors have shown its potential to reduce energy consumption by up to 40% compared to a conventional compressor with a synchronous motor and fixed speed/cooling capacity running on/off.

RESULTS

Intensive tests in labs and in the field have shown solid savings in energy consumption. The table beneath shows the effect on the cabinet's energy efficiency using a variable speed compressor but with the fluorinated gas R404A. It was observed to use 30% less energy compared to the identical system using a fixed speed (on/off) compressor. However, with the additional change of utilizing R290 (propane) as a refrigerant, the cabinet's energy efficiency was improved by a further 9%.



Additional savings come from secondary effects, which include the scheduled (hot gas) defrosting of the cabinet and the full integration of application functions into one controller, such as fan and illumination control.

By adopting new compressor technology to a conventional application and tailor a solution for plug-in cabinets in discount retail stores; immense savings in total cost of ownership have been enabled and have become a major success for the system manufacturer with approximately 600,000 pieces in the market today.

SUMMARY

Secop is now adapting the controls for variable speed compressors for the North American market, i.e. for 115 Volt 50/60Hz. The demand will come from strengthened policy that requires compliance with more stricter energy regulations in the near future. The integrated controller for food retail cabinets is under development and will be released in 2015. The controller can be modified to suit all other cabinet types where the energy efficiency is a major buying criterion.

SECO



Visit for more information

www.embraco.com

Contact information

Marek Zgliczynski

marek.zgliczynski@embraco.it

ABOUT THE COMPANY

Embraco is a global market and technological leader in hermetic compressors for refrigeration, with a clear mission to provide innovative solutions for a better quality of life. As one of the pioneers in the development of environmentally friendly products, Embraco reinforces its commitment to global sustainability by offering a full range of high efficiency compressors and condensing units.

With factories in Brazil, Italy, China and Slovakia and a production capacity of 36 million compressors per year, Embraco is a truly global company. Embraco produces electronic systems to make intelligent household and light commercial appliances.

Energy efficiency improvement in light commercial refrigeration systems

INTRODUCTION

The main purpose of this case study is to promote the use of hydrocarbon (HC) refrigerants and variable speed compressor technology in light commercial refrigeration systems by demonstrating the simplicity, as well as the benefits, of substituting HFCs refrigerants with hydrocarbons. To show this, the case study will analyze the substitution of a HFC compressor with a conventional on-off HC compressor as well as the switching of an compressor with variable cooling capacity using propane for a conventional HFC compressor. All information presented in this article comes from actual measurements of selected appliances.

Both studies presented here represent energy consumption levels of plug-in vertical freezers. The first example is a glass-door vertical freezer with 14 cuft of internal volume and the second one is a solid door vertical freezer manufactured from stainless steel with an internal volume of 20 cubic feet; both are used as cooling equipment for retail stores, supermarkets and restaurants. The original configuration of the selected systems were manufactured with Embraco compressor models NT2178GK and NEK2150GK using R404A and R507 refrigerant respectively. The condensers and evaporators both utilize fans, so both heat exchangers have forced air circulation. A standard capillary tube is used as the expansion device and the control unit of both systems is a standard electronic thermostat with a temperature range from 14°F to -13°F. Both systems are designed to climate class 4.

SUMMARY

R290 was selected as a substitute for the original refrigerants R507 and R404A. Propane is a natural refrigerant with a minimal environmental impact and possesses good physical properties for this type of application. The configurations of all refrigeration systems tested were almost identical, without any component change. Condensers, evaporators, piping, fans and all other components remain the same, except in the case of the glass-door freezer where high efficiency fan motors and LED lighting were installed. The same thermostat can be used again. For this comparative testing, compressors and filter dryers obviously have been changed. Refrigeration systems were tested in an environmental chamber. Temperature stability of the chamber was $\pm 0.9^{\circ}\text{F}$. Relative humidity during the testing was $\pm 3\%$ from set point. Placement of the refrigeration system during the test has been defined by the standard. Accuracy of the data acquisition system for temperature was $\pm 0.54^{\circ}\text{F}$, for pressure 0.2% and all electrical values were measured with accuracy 1%. All results from measurements are listed in Tables 1 and 2.

TABLE 1. RESULTS OF GLASS DOOR VERTICAL FREEZER TESTING

	HFC	HC
Compressor	NT217BGK	NT21770U
Compressor Type	on-off reciprocating	on-off reciprocating
Refrigerant	R404A	R290
Ambient temperature / Rel. humidity	86°F / 55 %	86°F / 55%
Refrigerant charge	14oz	4.8oz
Thermostat setting	62.6°F	62.6°F
Energy Consumption per 24 hours	14.400 kWh	8.219 kWh(*)
Energy consumption comparison	Reference	-42.9%

OPERATIONAL COST FOR END USER

Data from measurements can be used to predict operational costs of each specific system. Service and maintenance costs are not included in this calculation.

RESULTS

From the analysis presented in this article, it is clearly demonstrable that systems using HC refrigerants show an improved performance in all parameters. System energy consumption and environmental impact have been significantly decreased. There is an energy consumption reduction from 37.5 % to 42.9% respectively when using VNEK213U and NT2170U and carbon dioxide emission reduction in the range 41 – 46% that represents an excellent option to meet future energy regulations.

TABLE 2. RESULTS OF SOLID DOOR VERTICAL FREEZER TESTING

	HFC	HC
Compressor	NEK2150GK	VNEK213U
Compressor Type	on-off reciprocating	variable speed recipro
Refrigerant	R507	R290
Ambient temperature / Rel. humidity	86°F / 55 %	86°F / 55%
Condensing temperature	109°F	98.4°F
Evaporation temperature	- 11.7°F	-14.3°F
Refrigerant charge	14.8 oz	3.9 oz
Power (before turn off of the compressor)	606.2W	384.7W
Thermostat setting	62.6°F	62.6°F
Energy consumption per 24 hours	13,829 kWh	8,641 kWh



Commercial refrigeration

Introduction

Since the last GUIDE to Natural Refrigerants in 2013, there has been a big uptake in the use of natural refrigerants in North America's commercial refrigeration sector with the amount of stores using natural refrigerants standing at 409, compared to 200 in 2013, showing a doubling in the intervening two years between GUIDES. But it is not just the numbers that have increased, there has also been an increase in the choices retailers have, with a marked increase in the installation of transcritical stores, which in combination with cascade and secondary stores are further sidelining the usefulness of HFCs.

This spike in popularity for natural refrigerants is due to a combination of incoming policy changes, advancements in technology – especially for warm-ambient climates – and a confidence that these technologies can work in North America. However, the market is still developing, with the availability of training still remaining in need of strengthening. Optimism about the future of this sector is among the highest for natural refrigerants in North America but it is agreed that more policies favoring natural refrigerants and a lower initial cost would give a huge boost to a market in the midst of a large transition; which has over 37,000 supermarkets in the U.S. alone. Thankfully, efforts are being made both federally and at the state level in the United States and Canada to incentivize the uptake of natural refrigerant-based equipment.

409 stores in North America currently using natural refrigerants

139 CO₂ transcritical stores in Canada and 52 in the United States



When searching for energy and eco-friendly refrigerant solutions, trust the Sporlan leaf.

CO₂

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get the job done
under pressure
all day, every day.**



New
for 2015

Supermarket customers who use Sporlan CO₂ flow control products and Micro Thermo Technologies™ controls are assured their refrigeration systems operate reliably and efficiently while being constantly monitored by state of the art digital controls. High pressure CO₂ systems need heavy duty, ultra reliable components that are dependable, trouble free with economical life-cycle costs and the lowest possible carbon footprint. Facility and maintenance engineers in-the-know prefer Sporlan and Micro Thermo Technologies. Have the confidence that your CO₂ refrigeration requirements are covered with systems, spare parts and integrated facilities management tools from companies with more CO₂ experience in North America than anyone else.



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CO₂ Transcritical Stores

IN : 2015

139
CANADA

52
U.S.

11 BRITISH COLUMBIA

15 ALBERTA

2 SASKATCHEWAN

2 MANITOBA

1 WASHINGTON

1 WISCONSIN

1 INDIANA

2 ILLINOIS

20 CALIFORNIA

1 OKLAHOMA

NEWFOUNDLAND
AND LABRADOR 2

QUÉBEC 94

ONTARIO 12

NEW BRUNSWICK 1

MAINE 2

MICHIGAN 1

MASSACHUSETTS 1

CONNECTICUT 1

NEW YORK 8

VIRGINIA 1

OHIO 4

NORTH CAROLINA 1

TENNESSEE 2

GEORGIA 1

ALABAMA 1

LOUISIANA 1

FLORIDA 2

IN : 2013

68
CANADA

2
U.S.

IN : 2014

93
CANADA

14
U.S.

A TRANSCRITICAL BOOM IN THE UNITED STATES IN THE LAST TWO YEARS WHILE CANADA GROWS STEADILY

In the last couple of years, there has been substantial growth in the use of CO₂ in the commercial refrigeration sector in both Canada and the United States. What is more encouraging is that a significant amount of growth can be attributed to transcritical CO₂ systems, which do away with harmful fluorinated gases altogether. The continent has achieved a growth rate of over 200% in transcritical installations, with 191 systems in North America currently completed or planned as of August 2015 compared to 68 in 2013, including significant progress in the United States.

Within this growth, there are areas of particular interest, such as Québec. The province benefits from a positive policy framework, including direct incentives, as well as the presence of Sobeys, one of Canada's leading retailers, who has installed 58 of its 78 transcritical systems in Canada in Québec. As a result, the number of transcritical installations in Québec has jumped from 29 in 2013 to 94 this time around. This rapid uptake shows the swift turn the market is beginning to take, with retailers becoming more aware that upcoming regulatory changes

will have a huge impact on their business, with Sobeys noting they made the decision to move to CO₂ transcritical as they "did not want to relive another phaseout, a Montreal Protocol 3.0." In the U.S., California is leading the way in the adoption of CO₂ transcritical systems with 20 systems either installed or planned which is substantially higher than the second best, New York, which has eight CO₂ transcritical stores currently. Considering that two years ago neither state had any transcritical systems, this is an impressive rate of growth.

However as a whole, the growth of transcritical in the United States is emphatic with an increase from two in 2013 to 52 in 2015 when counting in planned installations for the rest of 2015 and beginning of 2016. Notably, the use of transcritical has also evolved to incorporate warm ambient temperatures, with installations in California, Georgia and Florida. This is a testament to the growing technological advancements of CO₂ transcritical solutions boosting the potential of CO₂ transcritical stores all across North America.

CASCADE SYSTEMS GROWING STEADILY IN THE UNITED STATES WITH LITTLE APPLICATION IN CANADA

As it can be seen in the cascade/secondary maps, the development of these systems in the United States has been substantial with the number of cascade/secondary systems increasing from 113 in 2013 to 199 in 2015, showing just under growth of 100% in a short period of time. The numbers in Canada are more stable with 17 supermarkets using CO₂ in secondary and cascade systems in 2013, whereas the number now is 19. While this number is much lower than the United States, it must be kept in mind that due to the lower-ambient temperature found in Canada, there is a distinct preference for the use of CO₂ transcritical systems.

The use of cascade and secondary systems in the southern half of the United States shows the use of natural refrigerants is varied. While transcritical solutions for high-ambient temperatures are still being trialed before full-commercialization, the use of cascade and secondary systems allow supermarkets to improve efficiency, increase safety and reduce the global warming potential of their systems.



CO₂ Secondary / Cascade Stores

IN : 2015

17
CANADA

199
U.S.

1 ALBERTA

AK

2 ND

4 WA

1 OR

2 IA

7 IL

2 UT

33 CA

3 OK

29 TX

1 SD

2 ID

1 IN

1 NE

2 KS

2 CO

5 MO

1 KY

QUÉBEC 12

ONTARIO 4

WI 3

MN 1

MI 4

NH 3

MA 12

CT 2

NY 7

NJ 3

PA 8

MD 1

WV 3

VA 4

OH 4

NC 4

TN 7

SC 3

GA 12

AL 1

MS 5

FL 13

LA 1

AR 3

IN : 2013



IN : 2014



Each Nation and each Industry Sector bears an individual responsibility in the fight against climate change.

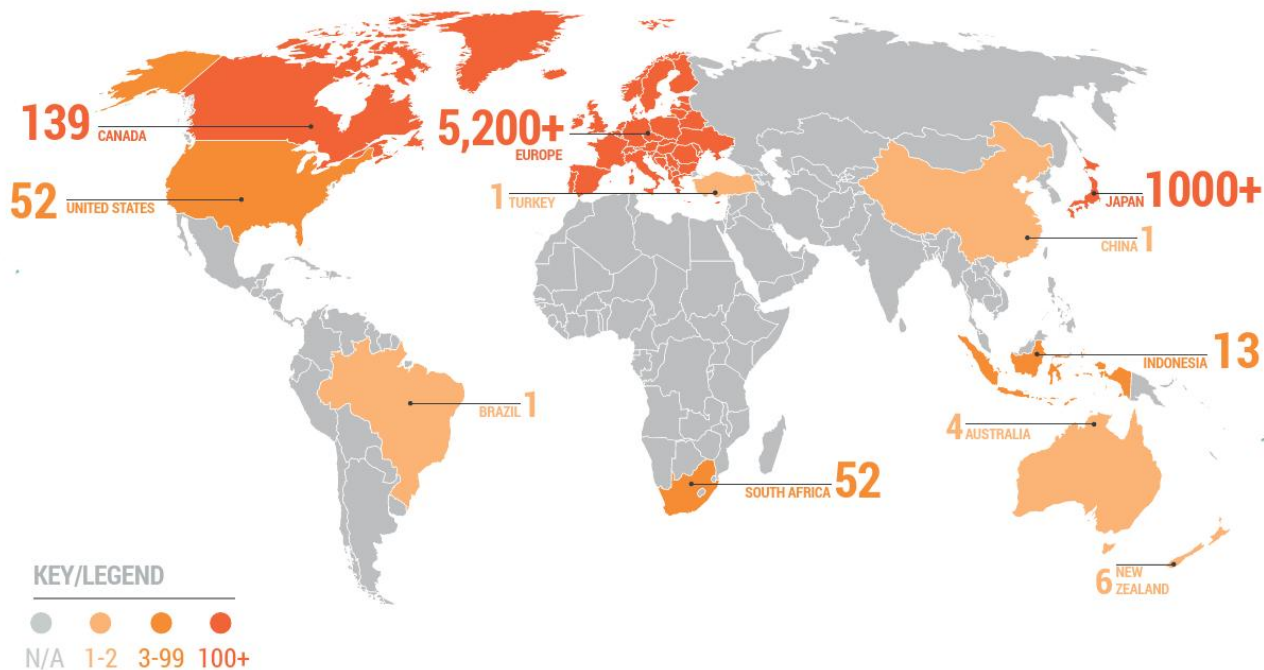
The refrigeration, heating and cooling industry recognises the role it can play to reduce direct and indirect emissions of greenhouse gases.

The Organisations who endorse this statement call upon the National Governments to responsibly shape today the climate opportunities of tomorrow, and acknowledge the potential of Natural Refrigerants.

Support the statement today on

www.thenaturalvoice.org

Over 6,500 CO₂ transcritical stores worldwide



CO₂ COMMERCIAL REFRIGERATION GROWING IN ALL MAJOR MARKETS ABROAD

In the markets abroad, CO₂ stores are growing fast in regions such as Europe and Japan. In Europe, CO₂ transcritical stores grew by 117% from 1,330 stores in 2011 to 2,885 in 2013. In 2015, this number currently stands at more than 5,200 super-markets. It is predicted that starting in 2016, more than 6,000 CO₂ transcritical racks will be added to the European market each year. Following that rationale, in 2020 there will be more than 32,000 CO₂ transcritical systems. By 2025, the number could double to more than 64,000.

In Japan, according to data collected from end users and system manufacturers, the number of CO₂ transcritical stores has increased from 190 in March 2014 to 1,000 in June 2015, which is a 500% increase in just over a year. The Japanese market is led by end users such as Lawson and AEON. Lawson is aiming to become

the world's number one food retailer using natural refrigerants, with currently 700 CO₂ transcritical stores. AEON is planning to exclusively use CO₂ as a refrigerant in new stores starting in 2015 and retrofit their existing 3,500 stores gradually with CO₂ systems.

While China's commercial refrigeration sector is currently still in its infancy, with eight stores using CO₂, including one being transcritical, there is an expected upward trend in this country as natural refrigerants continue their ascendancy in the Chinese market. Other areas of interest show that transcritical has made an impact include Turkey, Australia, New Zealand and South Africa, where there are currently 52 transcritical CO₂ installations adding to the grand total of CO₂ transcritical to over 6,500 globally.

EJECTORS, PARALLEL COMPRESSION, MECHANICAL SUBCOOLING AND ADIABATIC CONDENSERS TO BOOST EFFICIENCY DOWN SOUTH

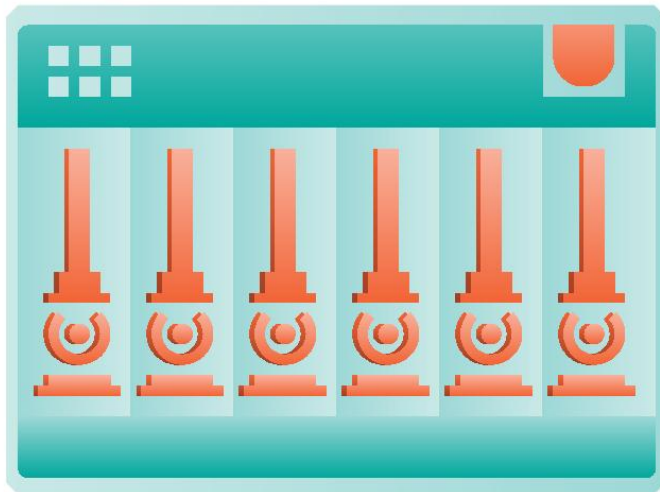
As CO₂ transcritical affirms itself further in northern climates, with some end users looking to make the system a standard in the northern U.S. and in Canada, there remains a disconnect with the south. The higher ambient climate in the south more often pushes temperatures to the critical point of CO₂ (88 F), above which more energy and refrigerant are required to produce efficiency similar to what is delivered below that temperature (the subcritical mode).

This area is one of the most exciting ones for development, with R&D in Europe, North America and Japan ongoing for the last decade with solutions looking to finally affirm themselves in high-ambient temperatures. To combat the loss of efficiency at high temperatures, component suppliers have begun developing and introducing ejectors and other technologies in place of the expansion valve in a

refrigeration system to increase efficiency. The idea is to remove the flash gas produced at higher temperatures. At a temperature of 104°F, the release of flash gas is estimated to be 48% at intermediate pressure, compared to 86°F where there is a flash gas release of approximately 30% at intermediate pressure.

The four most prominent solutions for improving the efficiency of transcritical CO₂ systems in warm ambient temperatures are high-pressure subcoolers, ejectors, parallel compression systems and adiabatic air-cooling. The data provided here, sourced from a leading system manufacturer, is in comparison to the use of a CO₂ transcritical booster system in high-ambient temperatures and shows the benefits these installations can have in warmer climates.

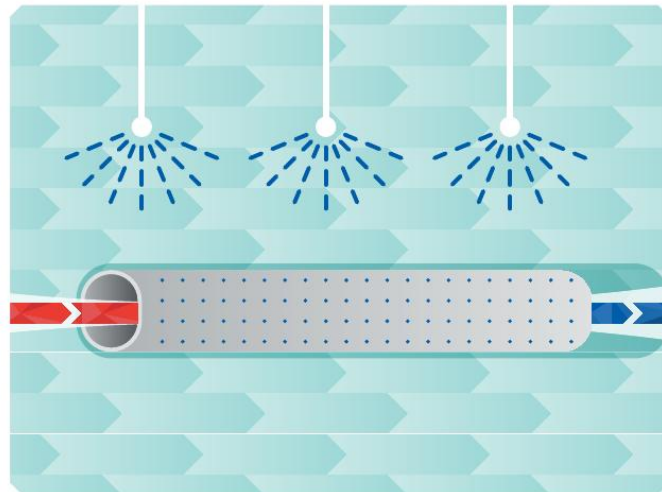
PARALLEL COMPRESSION SYSTEMS



In traditional DX systems, the flash gas is generated and removed in the MT and LT stages. In a parallel compression system, it is different and the majority of flash gas is removed at a higher pressure by the parallel compressor and hence, the energy penalty from the flash gas is less. In this way the parallel compression is quite similar to an economizer system in an NH_3 plant.

Peak savings: 15-20%
Annual savings: 6-10%
Availability: In use

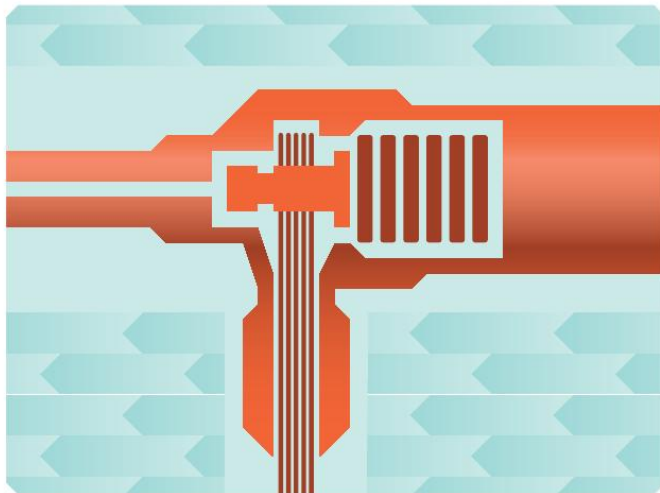
WATER SPRAY SYSTEMS & ADIABATIC AIR COILING CURTAINS



The adiabatic cooling system is based on the simple principle that evaporating water removes heat from its surroundings. In warm-ambient climates, this means that heat in the system can be lowered and in areas where water is scarce, the efficiency of the system means demand for water is reduced compared to other systems.

Peak savings: 20%
Annual savings: 6-10%
Availability: In use

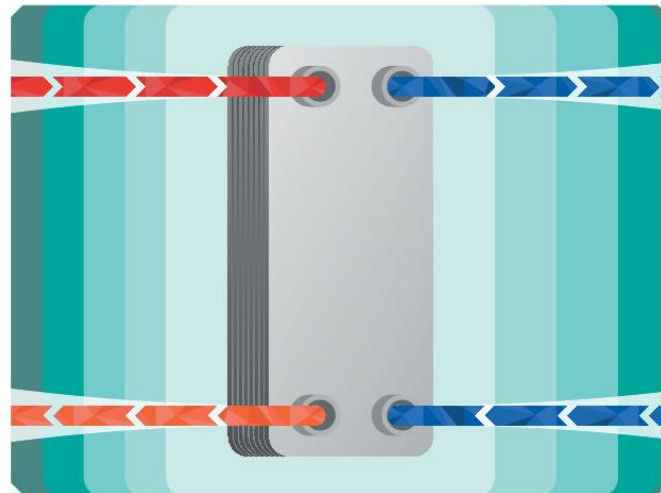
EJECTOR



An ejector usually consists of a motive nozzle, a suction chamber, a mixing section and a diffuser. The ejector works by converting internal energy and pressure-related flow work held in the motive fluid stream into kinetic energy, which can be done in either one or two phases.

Peak savings: 25%
Annual savings: 10-15%
Availability: In use

HIGH-PRESSURE SUBCOOLERS



High subcooling means that a condenser is full. Overfilling a system increases pressure due to the liquid filling of a condenser that shows up as high subcooling. To move the refrigerant from condenser to the liquid line, it must be pushed down the liquid line to a metering device. If a pressure drop occurs in the liquid and the refrigerant has no subcooling, the refrigerant will start to re-vaporize before reaching the metering device. Therefore, the use of high-pressure subcoolers abates this potential efficiency loss.

Peak savings: 25%
Annual savings: 6-10%
Availability: In use

BENEFITS OF EFFICIENCY AND INCENTIVES ARE BEGINNING TO ERODE COST PREMIUM OF NATURAL REFRIGERANT-BASED SYSTEMS

The benefits to the environment are beyond dispute. However, findings from the GUIDE survey as well as interviews with the industry clearly show that at, present, initial cost is still a barrier to the adoption of CO₂ transcritical systems.

The chart besides shows that the top three most agreed-with statements relate to cost and at the opposite end, the penultimate statement (i.e. the 2nd least agreed with) is related to a lack of financial support in adopting these systems.

As money is always a big consideration for companies, subsidies, taxes and incentives are all seen as exerting a strong effect on the adoption of natural refrigerant technologies in commercial refrigeration primarily, as they will affect the cost imbalance felt in the sector. There are, for example, examples of funding of energy-efficient technology from utility companies. States such as California are beginning to embrace this organic development that sees co-operation from supplier to end-user. An example of this incentive scheme is Southern California Edison (SCE), who is the primary electricity supplier for much of Southern California. Has a New Product Development & Launch (NPD&L) group whose sole purpose is to provide alternatives to energy consumers that lower energy consumption and cut demand during peak periods.

There is also an added scope for energy saving in commercial refrigeration through the use of integrated systems. These systems combine traditional commercial refrigeration with waste heat reclaim, utilizing it for air conditioning and hot water supply. With the addition of components such as ground source heat pumps, supermarkets are able to further reduce their energy consumption and reliance on the grid.

Cost considerations tops list of trends in commercial refrigeration



Initial cost of natural refrigeration systems is currently the major barrier to adoption



Higher number of natural refrigerant components manufactured in North America would increase CO₂ uptake in commercial refrigeration



The total cost of ownership for NR solutions will incentivize investments in these technologies



CO₂ cascade technology is likely to be more popular than CO₂ transcritical



CO₂ transcritical in commercial refrigeration will become standard only in Canada



CO₂ transcritical technology in commercial refrigeration will become mainstream in North America within 5 years



The North American region will overtake Europe in the annual rate of CO₂ transcritical installations within the next 10 years



There are adequate financial incentives for the uptake of natural refrigerant solutions



Qualified technicians are available



EPA GreenChill Partner with 34 Platinum-certified stores

[On why they chose CO₂ transcritical] We [Sobeys] know that there will be a problem with new synthetic refrigerants, and another 'Montreal Protocol' that says HFOs have to be phased out in 2030 or 2040.

Founded: 1907

Headquarters: STELLARTON, NOVA SCOTIA

Number of Stores: 1,500

Natural refrigerant-based stores: 81



EPA GreenChill Partner with 2 Gold certified stores

"We [Target] believe that advancing CO₂ technologies in supermarket refrigeration systems is absolutely viable. Which is why Target is changing its prototype for new stores from R404A to hybrid CO₂ solutions."

Founded: 1902

Headquarters: MINNEAPOLIS, MINNESOTA

Number of Stores: 1,800 (U.S.)

Natural refrigerant-based stores: 7



EPA GreenChill Partner with 3 Platinum, 3 Gold and 3 Silver-certified stores

"We are testing to see what works, what technicians can handle and what we can afford to do."

Founded: 1980

Headquarters: AUSTIN, TEXAS

Number of Stores: >360

Natural refrigerant-based stores: 14



EPA GreenChill Partner with 1 Platinum and 1 Gold-certified store

"We are about ready to make it [CO₂ transcritical] our standard in new stores." [Hannaford Supermarkets]

Founded: 1867

Headquarters: BRUSSELS, BELGIUM

Number of Stores: IN U.S., FOOD LION (1,100) & HANNAFORD (>175)

Natural refrigerant-based stores: 3



EPA GreenChill Partner with 2 Platinum, 7 Gold
and 34 Silver-certified stores

First supermarket to use CO₂ transcritical solution in warm ambient temperatures in the United States

Founded: 2001

Headquarters: PHOENIX, ARIZONA

Number of Stores: >200

Natural refrigerant-based stores: 2



1 Transcritical store

"We installed a CO₂ refrigeration system in one corporate store in 2013 and our intent, moving forward, is to install this system in new corporate stores."

Founded: 1919

Headquarters: BRAMPTON, ONTARIO

Number of Stores: >2,000

Natural refrigerant-based stores: 1



EPA GreenChill Partner with 1 Platinum-certified store

"We will be installing more CO₂ transcritical systems in 2016 based on the success of the system installed at our Menomonee Falls store."

Founded: 1872

Headquarters: MILWAUKEE, WISCONSIN

Number of Stores: 156

Natural refrigerant-based stores: 1



1 Transcritical store

"We are opening around 150 new stores a year, so we intend to take the lessons from this project and be able to apply them to our existing store base as well as new stores."

Founded: 1901

Headquarters: CHICAGO, ILLINOIS

Number of Stores: 8,229

Natural refrigerant-based stores: 1

Policy drivers for natural refrigerants in commercial refrigeration

SNAP DELISTING RULE LOOKS TO GET RID OF R404A IN SUPERMARKET REFRIGERATION BY 2019

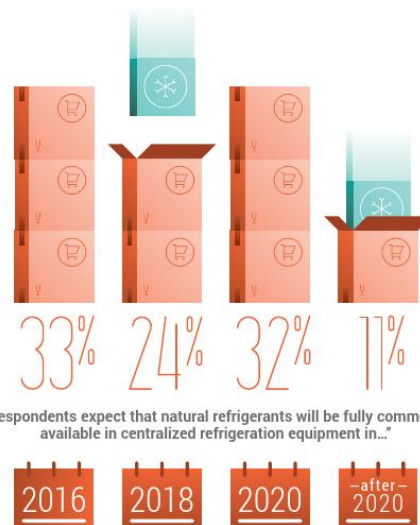
In 2014, SNAP proposed the potential delisting of the ubiquitous R404A among various other high-GWP HFCs as a refrigerant in new commercial refrigeration equipment and retrofits from January 2016. However, in its final rule, the agency moved those dates backwards by at least one year.

For example, for retail food refrigeration applications, the use of R404A, R507A and other HFCs in new supermarket systems will be deemed unacceptable as of January 1, 2017. R404A, R507A and other HFCs will be delisted from use in new remote condensing units in supermarkets as of January 1, 2018.

In retrofit systems, the same refrigerants will become unacceptable one year from the date of publication of the final rule in the Federal Register (July 20, 2016). Although, it has been clear for some time that R404A's days were numbered, with manufacturers already moving away from it, this ruling will serve as a further incentive to those who have not yet cemented their future plans.

EPA'S GREENCHILL PROGRAM

GreenChill is a partnership operated by the EPA to help food retailers in their mission to reduce refrigerant emissions and as such, decreasing their impact on the ozone layer and climate change. The initiative, which was launched in 2007, is a government-backed scheme that looks to reward stores that install environmentally friendlier systems in their supermarkets via the GreenChill Store Certification program. GreenChill partners include food retailers, manufacturers of advanced refrigeration systems and manufacturers of retrofit chemicals and secondary fluids.



Industry expects full commercialization of natural refrigerant-based centralized systems before 2020

At ATMosphere America 2015, industry stakeholders were polled as to when they expect full commercialization of natural refrigerant-based centralized commercial refrigeration equipment in North America. With over half of the audience indicating they expect this to occur by 2018 and nearly 90% believing it will happen before 2020, it is clear that the market expects the transition to happen relatively quickly. Shecco's market research shows that growth is occurring at triple figures in both Canada and the United States, backing up this belief.

To qualify for GreenChill's Store Certification, a store must meet specific criteria including:

- » The store must only use refrigerants with zero ODP
- » The store must only use refrigerants that have been found acceptable by EPA's SNAP program for use in retail food
- » The store must achieve a store-wide annual refrigerant emissions rate of 15% or less
- » All newly constructed stores must also be leak tight at installation to prevent future refrigerant leaks

Once fulfilling this criteria, stores are able to receive a Platinum, Gold or Silver-level certification. At present there are:

- » 10 Platinum-certified stores
- » 31 Gold-certified stores
- » 81 Silver-certified stores

CALIFORNIA'S NEW HFC MEASURES TO TARGET COMMERCIAL REFRIGERATION AS LOW-HANGING FRUIT

Commercial refrigeration has been identified as a clear target for the reduction of HFCs in California's upcoming new measures. A concept note for developing a strategy to reduce short-lived climate pollutants (SLCPs) noted that commercial refrigeration is accountable for 40% of California's emissions.

This is an area where it is felt that natural alternatives exist, especially in the use of CO₂, which can be built upon in the intervening 15 years. However, it is noted by the California Air Resources Board (ARB) that incentives and funding mecha-

nisms need to align with the commitment of the private sector. Other measures the ARB is looking into include creating regulatory requirements to use low-GWP refrigerants in new commercial refrigeration systems by realistic dates for suppliers and end users. In addition to this, ARB is also considering potential future bans or regulatory requirements or programs for existing systems.

If these laws come to pass – the submission will be complete in Spring 2016 – then a clear precedent will be set in the United States on how much can be achieved at the state level. It is possible that if this framework were to become ubiquitous across all fifty states, then the United States would lead the world in efforts to phase down and replace HFCs.

QUEBEC: INCENTIVES HELP DRIVE INTRODUCTION OF CO₂ TRANSCRITICAL SUPERMARKETS

As announced in its Climate Change Action Plan (2013-2020), Quebec continues to incentivize reductions of HFC emissions in the refrigeration systems of supermarkets, warehouses and ice arenas. The refrigeration Optimization Program (OPTER), administered by Quebec's Ministry of Natural Resources and Wildlife, was an investment grant scheme that encouraged refrigeration system owners to transition to more environmentally friendly systems, including in commercial refrigeration. The scheme offered up to CAD\$125,000 to owners of refrigeration systems to make the shift to more climate friendly refrigerants, reducing the refrigerant charge by installing secondary loops and integrating refrigeration, heating and ventilation systems. As of 2013, the scheme continues under a broader "EcoPerformance" framework, which supports exclusively CO₂ as a refrigerant in projects involving refrigeration systems. The program runs until March 2017.

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Industry viewpoint

ON COST...

Marc-Andre Lesmerises – CEO, Carnot Refrigeration

Over the past five years, the total cost of CO₂ systems – first cost, installation and operating cost – has declined to the point where they are now competitive with traditional DX systems using an HFC (like R507). The first cost alone has dropped as well.

Kevin Christopherson – Director of Maintenance and Purchasing, Roundys

All told, the transcritical system's equipment and installation costs were estimated by the Milwaukee Journal Sentinel to run \$1.8 million. The actual costs came in under that amount – and ended up being about 1% less than those of the prototype (R507) system.

ON FUTURE EXPECTATIONS...

Sporlan team

We anticipate a significant demand for CO₂ transcritical stores due to the improved cost of components, and design/process improvements. CO₂ transcritical stores are a recent development in North America, and currently there is no standard in the U.S. Continuous improvements to heat reclaim and defrost strategies, as well as energy reductions and increased technician training, will greatly increase adoption.

ON NATURAL REFRIGERANTS IN WARM-AMBIENT TEMPERATURES...

Paul Bevington – Business Development Manager, Carter Group

Warm climate natural solutions are available and proven, however; for transcritical CO₂ there are still limitations. In these most harsh climates other possibilities, need to be considered such as controlling condensing temperatures in transcritical TC CO₂ or looking at alternatives such as hydrocarbons.

Sporlan team

As new technologies are developed we believe this efficiency limitation in southern climates will start to go away. It's important to keep in mind that CO₂ has only been a focus for a few years in North America.

Paul Bevington – Business Development Manager, Carter Group

The climatic challenges do mean there may be a need for more than one natural solution in North America. However, there is the potential for North America to exceed the current levels of activity currently seen in the EU. Key to this are the retailers themselves. While legislation can force their hands to a certain extent and is moving in that direction for an accelerated rollout they hold all of the cards.



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Contact information

Marc-André Lesmerises, P.E.

marcandrelesmerises@carnotrefrigeration.com

ABOUT THE COMPANY

Carnot Refrigeration is a Canadian company headquartered in Quebec and established in 2008 with the goal of addressing the HVAC&R industry's failure to provide industrial and commercial clients with a thermodynamic option that would diminish environmental impact. Carnot Refrigeration makes a conscious effort to design refrigeration systems and heat pumps that cut down on the use of polluting refrigerants. It has taken the lead in its field by creating high-efficiency refrigeration systems designed by specialized engineers and manufactured in an environmentally controlled plant or at a constraint-free site. Carnot Refrigeration is experienced in meeting the needs of sports facilities (arenas), supermarkets, distribution centers and the agri-food industry.

CO₂ transcritical Aquilon is emerging for Bell Canada's server rooms

INTRODUCTION

In summer 2012, Bell Canada, a Canadian telecommunications company, asked Carnot Refrigeration to develop the very first CO₂ transcritical refrigeration system for server rooms. Bell Canada saw Carnot Refrigeration as a company capable of exceeding expectations with the installation of this one-of-a-kind system.

ABOUT THE SYSTEM

The project involved replacing an R22 refrigeration system with a CO₂ transcritical system with a cooling capacity of 105 kW. The R22 system had to remain in operation until the Aquilon system was fully installed. The work took place in an Ottawa server room owned by Bell Canada, and the entire turnkey project was orchestrated by Carnot Refrigeration. The end result is a new system that is greener, more energy efficient, 100% CO₂, cheaper to maintain and less likely to leak refrigerant.

The process began with the development of a prototype in Carnot's laboratory and involved in-depth construction in areas such as the mechanical design, the electrical boxes and the integrated control system. This development involved close collaboration between the engineering departments of Bell Canada and Carnot Refrigeration, and the construction was optimized for maintenance, so all parts and equipment are placed deliberately to allow for easy maintenance. Additionally, each part can be withdrawn from the front of the machine.

This process resulted in an Aquilon system of 105 kW that is equipped with two semi-hermetic reciprocal compressors, an integrated control system and stainless steel piping. The system is designed to withstand a pressure of 120 bar, which means it can be shut down and maintain its refrigerant charge without issue. In addition, the system integrates Rain Cycle technology, patented by Carnot Refrigeration, which allows for the continuation of refrigeration in the room without using the compressors, resulting in significant energy savings when outside conditions permit.

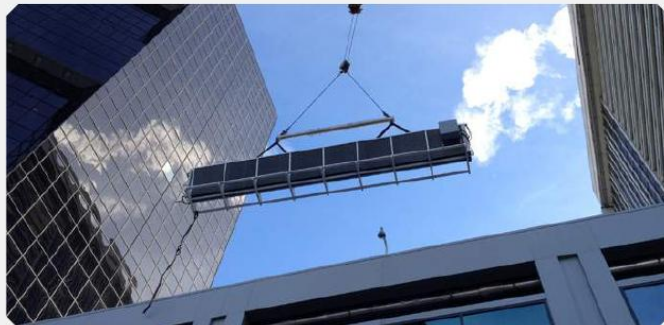
The installation of Aquilon was a turnkey project entirely managed by Carnot Refrigeration in terms of electricity, refrigeration, structure, ducting, commissioning as well as in obtaining permits and accreditations from the Canadian Technical Standards and Safety Authority (TSSA). When designing the system, everything has been thought of to minimize installation costs and time of installation on site.



RESULTS

After more than seven months of operation, from October 2014 through April 2015, the 105 kW Aquilon system has operated without its compressors using the Rain Cycle technology during 3,846 hours out of a possible 4,008 hours, more than 95% of the time. Until now, the total electricity consumption is 20,191 kWh, and the temperature of the server room is maintained at 25°C. Although Aquilon has not gone yet through its first summer, the first results are very promising and go beyond expected performances. Several other projects are already underway between Bell Canada and Carnot Refrigeration, clearly demonstrating that the first results have impressed Bell Canada.





Transcritical CO₂ system as replacement to R22 at Alexis-Nihon Plaza

INTRODUCTION

CO₂ transcritical refrigeration in supermarkets is not a new concept in North America. However, while the technology is reliable and proven it has yet to prove itself in particular circumstances. Sobeys had, in its projects, one of those challenges that would make CO₂ transcritical refrigeration more mature. In the heart of downtown Montreal, IGA Atwater supermarket is doing business within the Alexis-Nihon Plaza, corner of St. Catherine and Atwater. With its traditional refrigeration system becoming obsolete, measures had to be taken to replace it. Sobeys, for financial, ecological and efficiency reasons, has made CO₂ transcritical its default refrigeration solution, both for renovations and new constructions. The challenge in this case was to retrofit the refrigeration system in one of the busiest supermarkets in the province of Quebec without stopping operations. The challenge was at several levels, logistically and technically, and many departments at Carnot Refrigeration were tested: engineering, project management and production.

ABOUT THE SYSTEM

The project consisted of replacing the two old R22 systems with a CO₂ transcritical system with a capacity of 400 kW. As store operations needed to continue during the project, it was necessary to transfer the R22 load of the system to the CO₂ system gradually and progressively. Carnot Refrigeration and its subcontractors orchestrated the complete refrigeration part of the project. The new system is more environmentally friendly and energy efficient, and using



Visit for more information

www.carnotrefrigeration.com

Contact information

Marc-André Lesmerises, P.E.

marcandresmerises@carnotrefrigeration.com

ABOUT THE COMPANY

Carnot Refrigeration is a Canadian company headquartered in Quebec and established in 2008 with the goal of addressing the HVAC&R industry's failure to provide industrial and commercial clients with a thermodynamic option that would diminish environmental impact. Carnot Refrigeration makes a conscious effort to design refrigeration systems and heat pumps that cut down on the use of polluting refrigerants. It has taken the lead in its field by creating high-efficiency refrigeration systems designed by specialized engineers and manufactured in an environmentally controlled plant or at a constraint-free site. Carnot Refrigeration is experienced in meeting the needs of sports facilities (arenas), supermarkets, distribution centers and the agri-food industry.

CO₂ as a refrigerant, is less costly in terms of maintenance and less likely to leak refrigerant, while also providing a high level of reliability.

The system designed for the Atwater supermarket was divided into three equipment parts: the transcritical part, the subcritical part and a gas cooler. The transcritical part consists of eight semi-hermetic reciprocal compressors and integrated control. The subcritical part consists of two tanks and three semi-hermetic reciprocal compressors and integrated control. The gas cooler has eight very quiet fans, producing barely 48 DBA at 10 meters, which meets the strict criteria of the City of Westmount. The system incorporates two direct heat recovery circuits and a heat recovery system for domestic hot water.

One of the biggest challenges of this project was in the logistics of the installation and start-up of the system. In order to bring the system up to the mechanical room, it had to be brought through the Alexis Nihon Plaza. Since the floor of this facility was not strong enough, the system had to be delivered without its compressors, which were installed on-site by plant technicians from Carnot Refrigeration.



The elements composing the refrigeration system are located on three different levels. The gas cooler is four levels above compressors racks, and the cold rooms are two floors below compressors racks. The Carnot engineering team had to think long to ensure that such a layout would not cause problems to the system, both in terms of refrigerant circulation and oil management. In addition, there is only one door separating the grocery-shopping customers and the refrigeration system, which required that the system be as quiet as possible to avoid disturbing the customers.

RESULTS

The site of Alexis Nihon Plaza has been operating for nearly a year. Preliminary numbers show that, conservatively, this type of equipment could bring savings of around 10% per year in electricity usage alone. Maintaining the counter temperatures is done in a very accurate way. Defrosts are very effective and allow products to last longer, especially during accelerated passive defrost. Heat recovery from the compressors is used to heat the store, further reducing costs. In addition to eliminating HCFCs, a natural refrigerant system brings concrete monetary savings and refrigeration efficiency. There is no reason not to switch to natural refrigerant because it is possible to change a system, regardless of its configuration, situation or location.





First warm climate CO₂ transcritical store in southeast U.S.

INTRODUCTION

In 2014, Arizona-based grocer Sprouts Farmers Market entered the southeast United States in a big way. With one of its first stores in the metro-Atlanta area, the fast-growing healthy grocery store chain also brought the first CO₂-based, HFC-free supermarket refrigeration system to a warm weather market in North America.

Six years ago, Sprouts' corporate leadership set out to lead the industry in reducing its refrigeration-based carbon footprint. As part of that effort, Sprouts joined the EPA's GreenChill partnership in May 2010. GreenChill is an EPA partnership with food retailers to reduce refrigerant emissions and decrease their impact on the ozone layer and climate change. By April 2011, Sprouts had collaborated with Hillphoenix to earn GreenChill's highest award - platinum certification - for its Thousand Oaks, Calif. store. For its new Dunwoody, Ga. store, the grocer once again chose to work with Hillphoenix.

The transition to CO₂ as a sustainable alternative for supermarket refrigeration is booming in cool climate markets, with roughly 3,000 transcritical CO₂ systems operating worldwide in cool weather cities. Until now, the southernmost Hillphoenix Advansor transcritical CO₂ booster system in North America was located in Indianapolis. Sprouts and Hillphoenix set out to prove that transcritical CO₂ is a viable option for stores located in warm climates.

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Contact information

Derek Gosselin

derek.gosselin@hillphoenix.com

ABOUT THE COMPANY

Hillphoenix designs and manufactures commercial refrigerated display cases and specialty products, refrigeration systems, integrated power distribution systems and walk-in coolers and freezers. Our environmental improvements in alternative refrigerants and energy efficiency have helped take more than 2 billion pounds of harmful emissions out of the atmosphere since 1996. Today, Hillphoenix leads the industry with its Second Nature line of alternative refrigeration systems, which includes glycol, CO₂ and ammonia-based systems.

ABOUT THE SYSTEM

The Dunwoody Sprouts location runs on an Advansor transcritical booster system that entirely eliminates the use of environmentally harmful hydrofluorocarbons (HFC), which was for years the refrigerant of choice in the supermarket industry. One pound of leaked HFC refrigerant can cause more global warming than 2,000-4,000 pounds of carbon dioxide. Increasingly, food retailers are moving toward more sustainable refrigeration methods which include natural refrigerants like CO₂.

“Central to Sprouts’ identity is a genuine commitment to responsible retailing,” said Ted Frumkin, senior vice president of business development, Sprouts Farmers Market. “This innovative partnership with Hillphoenix helps Sprouts reduce our environmental impact, which we know is important to our customers and our team members.”

Although a transcritical system will work in any climate, it runs more efficiently in a cooler climate and less efficiently in a warmer climate. This is because CO₂ has a critical point of 87°F. Above that temperature the hot CO₂ gas in the condenser will not change to liquid as it cools like a synthetic refrigerant (e.g., HFC) would. During that time the CO₂ system operates differently and the efficiency is lower because of it.

This particular project came together as a perfect opportunity for Sprouts and Hillphoenix to prove transcritical CO₂ could work in warm climates. With most Sprouts stores located in high-ambient temperatures, the company was prepared to invest in making transcritical CO₂ work outside of northern regions. Hillphoenix engineers had recently completed the design of a warm-weather transcritical refrigeration solution, and Sprouts was preparing to enter the metro-Atlanta market, less than an hour’s drive from Hillphoenix’s Conyers headquarters.

“Sprouts has been working with the engineers at Hillphoenix ever since CO₂, ammonia and other alternative refrigerants first came out,” said Jerry Stutler, vice president of construction and facility engineering for Sprouts. “Now we believe that they have come up with a viable transcritical system design, and they can continue to monitor the operation of the system along with us.”



RESULTS

Energy efficient, economical transcritical CO₂ refrigeration systems are normally limited to cooler climates due to the limitations of air-cooled gas coolers. The key to Sprouts’ new system is a TrilliumSeries™ hybrid adiabatic condenser designed for Hillphoenix by Baltimore Air Coil.

“We worked with Baltimore Air Coil to develop a new product that’s a hybrid adiabatic condenser adapted for use with CO₂,” said Scott Martin, director, sustainable technologies at Hillphoenix. “Adiabatic condensers offer energy savings by providing lower system condensing temperatures than conventional air-cooled condensing systems, and they do that without the degree of maintenance, water consumption, or water treatment required by traditional evaporative condensers.”

With its new Dunwoody store, Sprouts aims to change the industry’s preconceived notions about warm climate operation of transcritical CO₂ systems, demonstrating that it is a viable option for retailers seeking a more sustainable, energy-efficient refrigeration option. And having the ability to utilize Hillphoenix’s The AMS Group as a single-point, turnkey project management and engineering services team helped Sprouts meet project goals.



Grocery store chain running CO₂ transcritical booster system in 'HOTLANTA'

INTRODUCTION

CO₂-based refrigeration architectures are more common in cooler climates. CO₂ transcritical booster systems — which rely entirely on CO₂ — are not considered an obvious solution in places like Atlanta. However, with increasing regulations prompting a shift toward sustainable alternative refrigerants, retailers are looking more closely at CO₂ transcritical booster systems to anchor their refrigeration operations, even in warmer climates.

With more than 200 U.S. locations, Sprouts Farmers Market, a Phoenix-based grocery chain that offers fresh, natural and organic foods, is among the first retailers in North America to do just that. They opened their first store in suburban Atlanta in July 2014, and when they did, they set out to prove CO₂ transcritical booster systems aren't only for cool climates.

Changing their refrigeration philosophy and moving to a CO₂ transcritical system architecture was a giant step for Sprouts, especially for this store in the hot, humid climate of Atlanta. To pull this off, they turned to OEM partner Hillphoenix, whom the company partnered with to earn an EPA GreenChill platinum certification in 2011. And Hillphoenix, seeing the challenge presented by installing a CO₂ transcritical booster system in a warm climate, turned to Emerson Climate Technologies.

ABOUT THE SYSTEM

A key enabling feature of the CO₂ transcritical booster system is an adiabatic condenser, which was designed to operate in high ambient temperatures. Adiabatic condenser cooling is the process of evaporating water into the air supply of an air-cooled condenser to pre-cool the air and improve refrigeration efficiency. The



Vist for more information

www.emersonclimate.com

Contact information

Andre Patenaude

andre.patenaude@emerson.com

ABOUT THE COMPANY

Emerson Climate Technologies, a business segment of Emerson (NYSE: EMR), is one of the world's leading providers of heating, air conditioning and refrigeration solutions for residential, industrial and commercial applications. The group combines best-in-class technology with proven engineering, design, distribution, educational and monitoring services to provide customized, integrated climate-control solutions for customers worldwide. The innovative solutions of Emerson Climate Technologies, which include industry-leading brands such as Copeland Scroll™ and White-Rodgers™, improve human comfort, safeguard food and protect the environment.

goal of this condenser technology is to keep the CO₂ below its critical point, thus maximizing system efficiencies.

Hillphoenix's rack refrigeration system featured four Copeland Transcritical CO₂ (semi-hermetic) compressors and three Copeland Scroll ZO compressors. Both models were designed for CO₂'s high-pressure requirements and benefit from its thermal properties.

Emerson's E2 Facility Management System was installed to oversee the CO₂ transcritical booster system, manage nearly 50 electronic case control units and optimize the facility's overall energy management profile. E2 helps improve performance in multiple ways:

- » Controls the variable speed of the fans on the adiabatic condenser in response to operating conditions
- » Optimizes compressor coefficient of performance (COP) by regulating system discharge pressures via Emerson's high-pressure CO₂ controller
- » Provides complete oil management control of all CO₂ refrigeration compressors
- » Communicates with and captures information from individual case control units
- » Provides complete control of building HVAC and refrigeration systems, and supports the retailer's energy and maintenance reduction strategies

E2 also allows Sprouts operators to run diagnostics, monitor the system remotely through Emerson's ProAct™ Service Center and, if necessary, shut down the system components before failure.

A unique aspect of a booster system is that the heat and CO₂ refrigerant from the low-temperature portion of the system flows directly into the medium-temperature portion of the system. This "boosting" of the refrigerant from the low-temperature to the medium-temperature portion of the system is where the system gets its name.

The pilot CO₂ transcritical booster system designed for Sprouts' Atlanta store utilizes a multitude of other Emerson Climate Technologies components, including:

- » Copeland Scroll ZO Compressors — for low-temperature refrigeration requirements (freezers)
- » Copeland Transcritical CO₂ (semi-hermetic) Compressors — for medium-temperature refrigeration requirements (dairy, produce and meat cases); includes variable frequency drives to prevent the compressors from cycling on and off too frequently
- » Emerson's E2 Facility Management System — provides complete CO₂ transcritical booster system optimization and facility-wide energy management
- » Discharge Air Controller — operates in unison with the E2 system and is capable of controlling heat and cool stages, fans, dehumidification devices and economizers using on-board I/O
- » High-pressure CO₂ Controller — optimizes high side pressures and liquid quality to the cases
- » XM Series Case Controls (pulse-width modulated) — integrates with the E2 system to maximize operating efficiencies through tighter temperature controls; present on nearly 50 cases
- » CoreSense™ Technology — advanced compressor diagnostics, protection and communications technology that allows technicians to make faster, more accurate decisions, resulting in improved compressor performance and reliability; present on all store compressors

RESULTS

Energy data and cost savings were not provided as of this writing. However, Sprouts has had no issues operating their Atlanta-area store efficiently and effectively on the transcritical system.

CONCLUSIONS

CO₂ transcritical booster systems have been used in Europe for nearly a decade. Adoption by the U.S. refrigeration industry has been slower due to a general apprehension about new (and, to many, unknown) technology. It's understandable why stateside end users are hesitant to switch to CO₂ transcritical booster systems. Concerns over operating pressures, maintenance levels and energy have prompted careful and steady evaluations to understand the true cost of ownership for their enterprises.

Emerson technology helped ease those concerns for Sprouts, however. And if this case study shows anything, it shows that employing a CO₂ transcritical booster system in warm climates isn't only possible — it's effective.

Industrial refrigeration

Introduction

With policy changes set for January 1, 2020, the North American industrial refrigeration industry is becoming increasingly natural. The already ammonia-dominant sector is in the process of completing its market take-over as ammonia is seen as one of the clear choices to replace older systems using the moribund R22 due to its attractive price, efficiency and mass availability.

However, in addition to traditional ammonia systems, there is a group of three “next generation” systems that are beginning to take hold in the marketplace. These three systems are: low-charge NH_3 , CO_2 transcritical and cascade/secondary. All three installation types increase safety, efficiency and the cost of refrigerant compared to traditional ammonia systems, with each system having its own idiosyncratic advantages.

It is not clear how this market will develop in the next five years, as the preferences for each of these next generation solutions vary between the United States and Canada as well as within states and provinces in these countries. What is clear, however, is that the role of natural refrigerants is vital to industrial refrigeration and will only continue to grow stronger.

187 low-charge NH_3 installations in Canada and 22 in the United States

8 CO_2 Cascade/Secondary systems in Canada, 53 in United States and 8 in Mexico

36 CO_2 transcritical installations in Canada and 10 in the United States



Boiler
Division

Level I

Level II

Ammonia
Division

Operator I

Operator II

Boot Camp

Operator III

PSM/ RMP

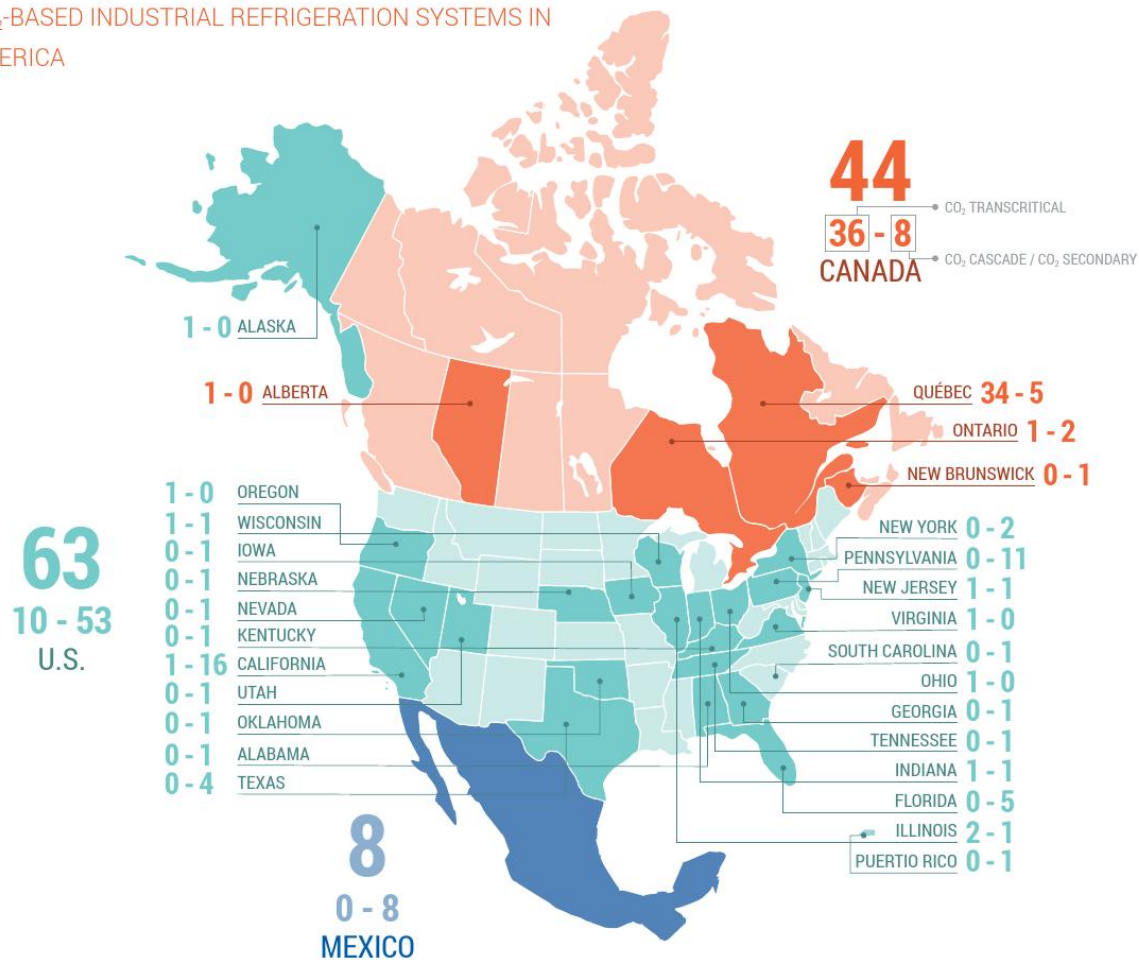
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USE OF CO₂-BASED INDUSTRIAL REFRIGERATION SYSTEMS IN NORTH AMERICA



GREATER UPTAKE OF CO₂/NH₃ SYSTEMS IN THE UNITED STATES TO BOOST EFFICIENCY AND ADDRESS SAFETY CONCERNS

Since the Montreal Protocol declared R22 would need to be phased out by January 1, 2020 – with “virgin” R22 being banned since 2010 for new equipment – the market has moved further towards ammonia. In this fallout, cascade and secondary systems have also increased in demand alongside ammonia systems, but this growth has been mostly regionalized to the United States where there are currently 53 installations compared to 8 in Canada. In these systems, NH₃ is used in the high stage to reject heat to the outside, whereas CO₂ is used in the low stage to absorb heat from the load to be cooled and to reject the heat to the ammonia high stage.

CO₂ TRANSCRITICAL IN NORTH AMERICA

In addition to limiting the ammonia charge and improving safety in CO₂/NH₃ cascade systems, CO₂ eliminates ammonia altogether in transcritical industrial systems, where CO₂ is the sole refrigerant.

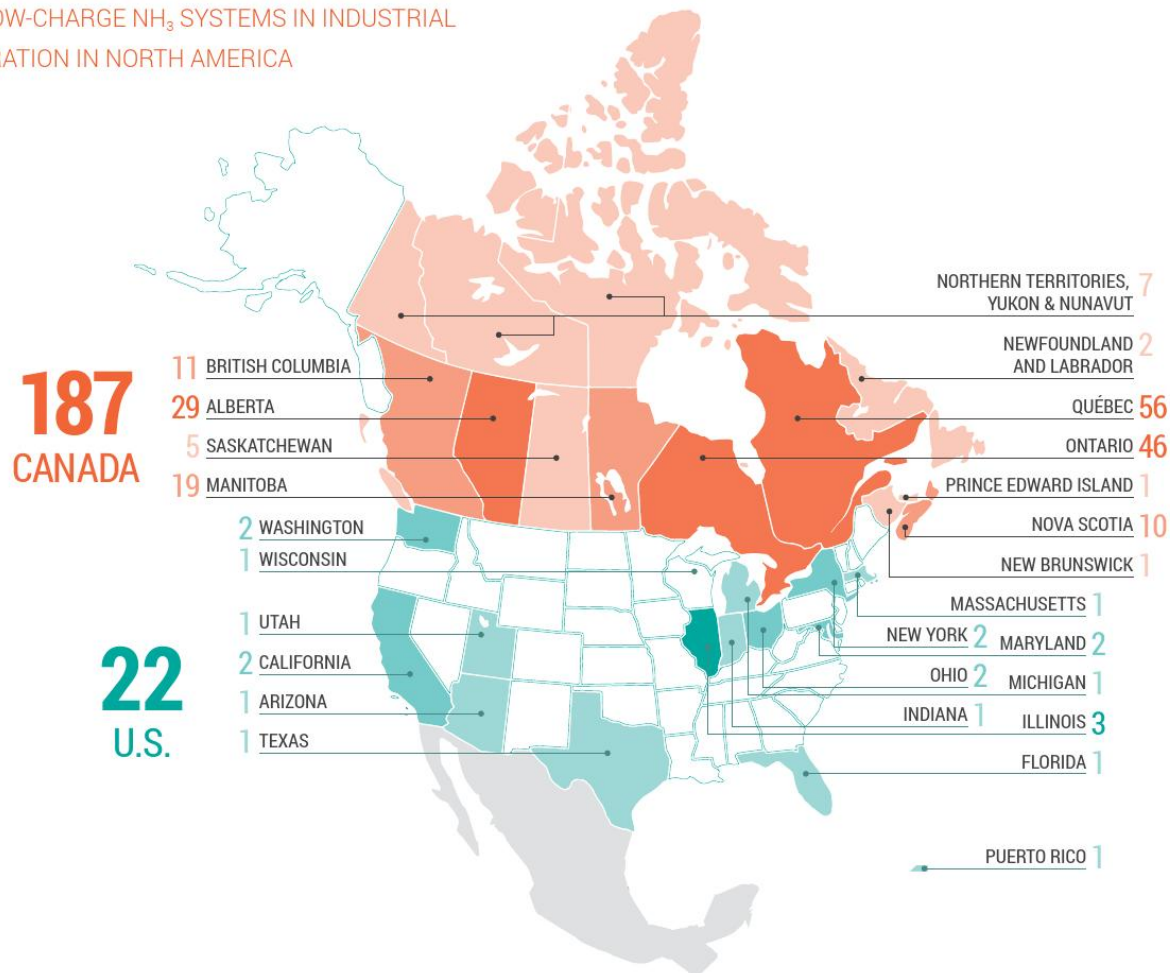
CO₂ transcritical is championed in Québec, which currently has 36 installations, compared to seven cascade/secondary sites. While the use of CO₂ transcritical systems currently lags behind that of low-charge NH₃ in Canada, the cumulative message is evident: Canada is further ahead in adoption of “next generation” natural refrigerant installations in the industrial sector than the U.S.

This separation of refrigerants in the refrigeration process means that ammonia can be uninvolved in more sensitive locations where there are safety concerns, such as areas where there are staff or food present. The ammonia is instead located in a central mechanical room or a rooftop compartment. A recent example of a cascade system using NH₃ and CO₂ in the United States shows the massive reduction in NH₃ charge, where the original amount of NH₃ of between 20,000 to 40,000 pounds was reduced to 6,400 pounds.

This could be related to the lack of SNAP approval for the use of CO₂ in applications such as ice rinks in the United States. However, a recent installation in an Alaskan ice rink showed that the use of CO₂ transcritical systems is gaining traction, which could lead to SNAP approval and increased adoption across the United States.

A CO₂ system carries with it higher pressures and needs to be appropriately fitted with relief valves as well as sensors and alarms in all parts of a facility, as is the case with ammonia. Potential hazards such as burst pipes can be neutralized in the form of machine rooms.

USE OF LOW-CHARGE NH_3 SYSTEMS IN INDUSTRIAL REFRIGERATION IN NORTH AMERICA



Take a deep breath. Now blow — you're exhaling one of the most abundant natural resources on earth. And the key to Hillphoenix® Second Nature® CO₂ refrigeration systems. CO₂ is naturally occurring and that makes CO₂ refrigerant plentiful, available and inexpensive.

CO₂ systems are environmentally friendly and cost less to install and maintain. But a CO₂ Second Nature system is only one of several refrigeration options available from Hillphoenix.

As the nation's leading refrigeration expert for the food retail industry, the company can design and build systems based on glycol, CO₂, ammonia or practically any other existing or future refrigerant. Hillphoenix introduced its first, sustainable refrigeration solution in the

1990s and today, enjoys a reputation among customers and peers alike as the industry's premier design and technology innovator. Tomorrow is already on the drawing boards and if today is any indication, it will take your breath away.



AS NATURAL

AS BREATHING.

Benefits of CO₂

- Significant HFC charge reduction with CO₂ Secondary & Cascade systems and 100% HFC elimination with CO₂ Booster systems.
- CO₂ offers improved compressor energy performance.
- Smaller diameters reduce copper pipe usage.
- Eliminates future refrigerant retrofits that interrupt sales floor activity.
- Much smaller carbon footprint.
- CO₂ is naturally occurring and delivers a GWP (Global Warming Potential) of almost 0.
- CO₂ refrigerant is abundantly available and inexpensive.
- Sustainable technology helps achieve GreenChill certification.

LOW-CHARGE NH₃ LEADING THE WAY IN CANADA WITH PRESENCE IN THE U.S.

The proliferation of low-charge ammonia systems is evident from the market map. While all areas show penetration for this technology, Canada is a clear leader in adoption with 187 current installations, Québec and Ontario having 102 installations between them. While the use of low charge ammonia is less prevalent in the United States, with 22 installations, the range of locations shows the varied temperatures it is able to work within, making it is a potential solution for the whole of North America. All together, these low-charge systems make up nearly 80% of next-generation industrial refrigeration installations.

The reduction in ammonia charge has various benefits, not least safety, with the area of contamination, in the event of a leak, greatly reduced. The cost of both the system and refrigerant are also much more palatable. In addition, as standardized systems, low-charge ammonia units are easier to maintain, take up less space and lower the on-site assembly costs.

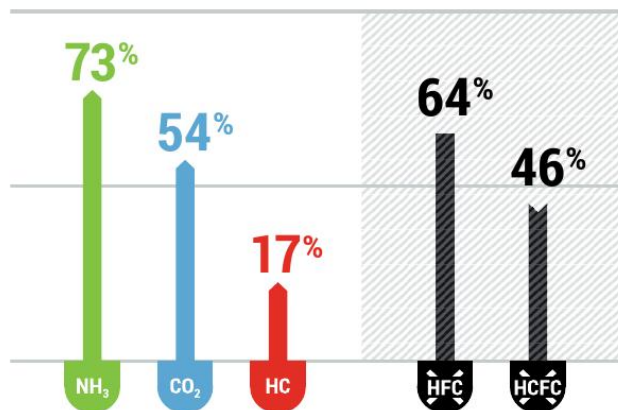
THE USE OF CO₂ IN ICE RINK COMPLEX LEADS TO LARGE ENERGY SAVINGS AND 'FREE HEAT'

The use of ammonia and R22 in ice rinks has typically been a standard in North America, however, in the last two years there has been experimentation with the use of different natural refrigerant-based systems in ice arenas. The use of low-charge NH₃ has been of particular interest and has improved efficiency, however, the use of CO₂ transcritical systems are looking to better this, improving efficiency while also having the ability to provide heating through the utilization of the waste heat generated by the transcritical system through heat recovery. This waste heat can then be used to provide heating to the ice rink or to other areas if the ice rink is in a complex, such as a community center.

While CO₂ transcritical installations boast massive energy savings, there are regulatory barriers preventing the widespread use of CO₂ in ice rinks across North

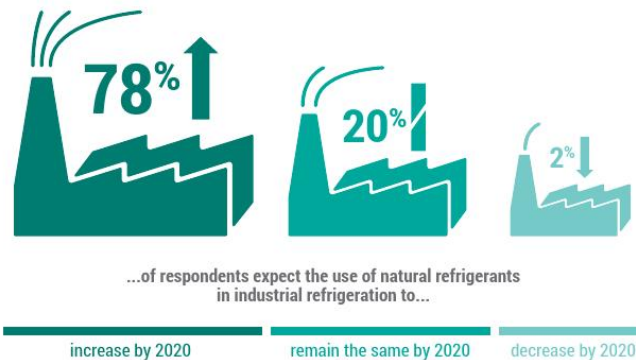
America. First, the use of CO₂ in ice rinks is currently not SNAP-approved in the United States. Second, in Canada, widespread adoption is prevented by certain provincial regulations. For example, the Horse-Power Regulation in Ontario sets restrictions for systems exceeding 100 horse-power, including CO₂ transcritical systems, essentially slowing down the adoption of such installations in the province.

The efficiency benefits of transcritical systems can range between 25-40%, with the utilization of waste heat leading to potential reductions of heating expenses of over 80%. Additional benefits include 60% less space required for the refrigeration equipment, as well as a 10% reduction in maintenance costs compared to conventional systems.



Natural refrigerants further sideline fluorinated gases in industrial refrigeration

From the industry survey responses, of those who work in the industrial refrigeration sector, ammonia was the most popular choice as a refrigerant, followed by HFCs and then carbon dioxide. With HCFCs now being phased out and HFCs likely to follow, the door is wide open for a completely “natural” industrial refrigeration sector, with a notably high percentage of users now utilizing CO₂.

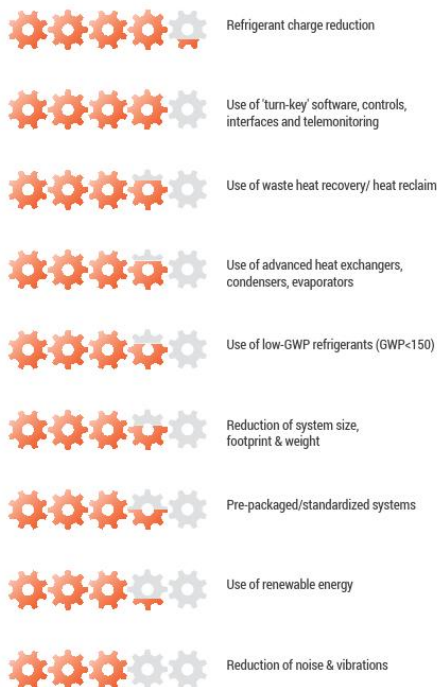


Industrial refrigeration's future is clear

In addition to the clear market concentration for ammonia, there is a clear prognosis that the future will be even greater. 77% of respondents believe that the use of natural refrigerants in industrial refrigeration will increase by 2020. Given its already strong position, the fact that 20% believe it will stay the same is a conservative affirmation that there is a future. Only 3% believe that the use of natural refrigerants will decrease – which, with upcoming regulations and increasingly safe and efficient natural refrigerant systems, is no surprise.

Policy drivers for natural refrigerants in industrial refrigeration

Charge reduction tops list of leading trends in industrial refrigeration



IAR-2 STANDARD COULD SIMPLIFY CHARGE-LIMIT RULES

The role of low-charge systems is becoming more important due to the threat of ammonia releases, which still has a large influence on regulatory standards. Therefore, codes and standards set by OSHA, IAR, ASHRAE, International Building Code, IMC and UMC all have various design references to the quantity of refrigerant in a system. Yet despite their best efforts, a lack of consistency runs through the definition of "low-charge size." Nonetheless, all regulations and standards are to be adhered to, regardless of the amount of ammonia used.

The IAR-2 industry standard on equipment, design and installation of closed-circuit ammonia mechanical refrigeration systems has undergone a major revision and is out for public review through 2015. One of the contributing factors for this revision is that the standard has undergone a major rewrite to help close the gaps with ASHRAE-15, Uniform Mechanical Code (UMC), NFPA-1, International Mechanical Code (IMC) and the International Fire Code (FC). The results of this review will have important implications for packaged and low-charge ammonia systems and include new definitions for equipment enclosures and secondary coolants. Due to the safety issues with ammonia, a common theme throughout the codes is the requirement to maintain sufficient access for operations, maintenance and emergency activities. Since some of the new low-charge technologies involve packaged or enclosed modular systems, where space is at a premium, it is important that the required access be provided.

Some changes to the IAR-2 standard could include additions relative to low-charge systems, notably the 100 horsepower compressor threshold, outline of equipment enclosures and a detailed set of criteria for packaged systems and ventilation design criteria for limited-charge systems. The specification of the different locations that refrigeration equipment can be located in a facility, along with the relevant thresholds, is particularly pertinent for low-charge packaged systems, which often arrange equipment in different locations than typical field-erected ammonia systems.

U.S. GOVERNMENT FOCUS ON SAFETY TO ENSURE RESPONSIBLE OPERATION OF NH₃ SYSTEMS

While the use of ammonia in industrial refrigeration is already a well-established trend within North America, there still remains hesitancy to fully accept it as an innocuous process. In order to improve the image of ammonia in spite of leaks and accidents, there is a greater emphasis on training as part of the industry's responsibility to ensure safe operation and clearer minds for all.

A formal endorsement of this attitude came in January 2015, when the EPA sent a clear message to the industry that companies must take responsibility to prevent accidental releases of dangerous substances like anhydrous ammonia through compliance with the Clean Air Act's (CAA) Chemical Accident Prevention Program.

The Chemical Accident Prevention program helps facilities comply with CAA requirements and prevent accidents. It includes the Risk Management Program, which requires facilities with more than a threshold quantity of certain regulated chemicals – 10,000 pounds for anhydrous ammonia – in use or in storage to develop a Risk Management Plan. It also includes "The General Duty Clause," which requires owners and operators of facilities that have regulated substances and other extremely hazardous substances to ensure that these chemicals are managed safely.

To enforce this and other standards, the EPA regularly inspects facilities with large amounts of ammonia. If the facilities fail to comply, then they are fined and could be closed down.

ENERGY INCENTIVES LEAD TO LOWERED COST FOR NEXT-GENERATION INSTALLATIONS

As more companies look to remodel their industrial refrigeration systems to adhere to environmental standards, there are state subsidies in the U.S. that helps businesses lower their energy costs and consumption. In addition to these, there are federal subsidies that can be utilized to assist in both improving energy efficiency and environmental impact. The U.S. and Canadian Energy Star program helps consumers who wish to purchase environmentally friendly products and also assists companies in their production facilities.

In addition to, energy utilities are offering subsidies to those using efficient technology such as low-charge systems, which offer a 15-25% energy efficiency

improvement over HFC-based refrigeration system and 5-10% gain over traditional ammonia systems. Utility companies are looking to aid these systems to help reduce demand, especially in peak times. These subsidies work in conjunction with the inherent cost savings of more efficient low-charge ammonia systems, which also have a lower installation cost, as well as lower operating and maintenance costs on top of reduced ammonia refrigerant costs.



Industry viewpoint

ON THE FUTURE...

Michael Lynch –

Vice President, Engineering, U.S. Cold Storage

US Cold Storage's ammonia-CO₂ refrigeration system, including all compressors, condensers and evaporators, was found to be on average 5.8% more energy efficient than a conventional ammonia system. The greater efficiencies of the low-temperature evaporators far outweigh the lower efficiency of the warmer-temperature units (at the docks, for example).

Bud Martinson –

Sales Manager of the Freezer Division, Mayekawa

While most of Mayekawa's end users employ ammonia in quick-freeze applications, closed ammonia-CO₂ systems are being more widely used. Processors want to eliminate ammonia in the processing area and use CO₂ there. The ammonia can then be isolated in the refrigeration room.

Gerard Von Dohlen –

President, Newark Refrigerated Warehouse

The future for refrigerated warehouses is the packaged system.

Paul Delaney –

Senior Engineer, Southern California Edison

We're working with manufacturers, inventors and customers to look at the new technology and how it can help with your business. We're trying to improve the adoption curve for new technology.

Jerome Scherer –

Managing Director, NXTCOLD

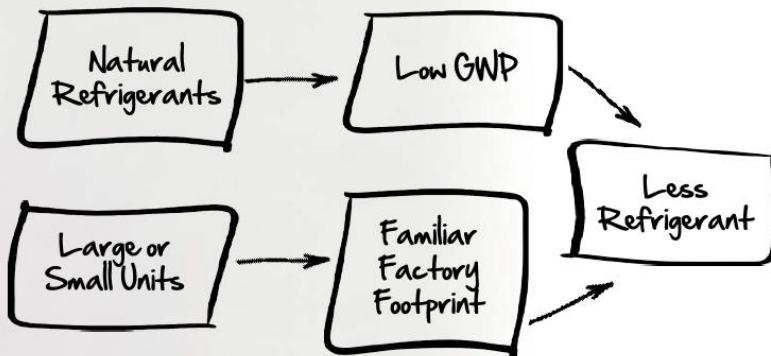
[On the impact of the R22 phaseout] The impact is nerve racking. Thank goodness there are some excellent refrigerant options as phaseout demands become more intense. Certainly large metropolitan areas benefit from the utilization of safe low-charge [ammonia] systems. With the advanced refrigeration concepts being developed, options for use in commercial and food store applications will soon become common. The move to natural refrigerants is a wonderful development nationwide and world wide.

Chuck Toogood –

VP Business Development, M&M Refrigeration

I believe that each application must be analyzed on a stand-alone basis. There will be applications that are individually best-suited for CO₂ transcritical, low-charge Ammonia and Cascade CO₂/NH₃ systems. However, I further believe that the Cascade CO₂/NH₃ solution is and will be best for the larger cold storage and processing facilities, especially those having lower temperature requirements."

the microgroove™ advantage



IT'S A GAME CHANGER

The use of natural refrigerants such as R744, propane and isobutane along with MicroGroove™ technology is changing the game of air conditioning and refrigeration (ACR) OEM product design.

OEMs are eliminating high-GWP refrigerants from ACR products while minimizing materials usage and increasing energy efficiency.

The resulting ACR products are smaller and lighter yet can be produced using familiar manufacturing methods.

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Vist for more information

www.carnotrefrigeration.com

Contact information

Marc-André Lesmerises, P.E.

marcandrelesmerises@carnotrefrigeration.com

ABOUT THE COMPANY

Carnot Refrigeration is a Canadian company headquartered in Quebec and established in 2008 with the goal of addressing the HVAC&R industry's failure to provide industrial and commercial clients with a thermodynamic option that would diminish environmental impact. Carnot Refrigeration makes a conscious effort to design refrigeration systems and heat pumps that cut down on the use of polluting refrigerants. It has taken the lead in its field by creating high-efficiency refrigeration systems designed by specialized engineers and manufactured in an environmentally controlled plant or at a constraint-free site. Carnot Refrigeration is experienced in meeting the needs of sports facilities (arenas), supermarkets, distribution centers and the agri-food industry.

Carnot Refrigeration at the heart of arenas

INTRODUCTION

The world of refrigeration is currently undergoing major changes. Refrigerants that have a detrimental impact on global warming and the ozone are being replaced with natural refrigerants, and the systems replaced with more energy-efficient ones. Carnot Refrigeration, a pioneer in natural refrigerant refrigeration technology, has developed a CO₂ transcritical energy-efficient system designed for arenas. While many arenas choose to go to ammonia, this highly efficient refrigerant is not the best solution for all projects. Therefore, more are choosing to use CO₂ transcritical refrigeration. The advantages of this option are numerous, including the possibility of direct heat recovery, maintenance simplicity, water tower not required, and so on. For these reasons, the City of Longueuil has chosen Carnot Refrigeration to provide a CO₂ transcritical system to upgrade its Cynthia-Coull arena.

ABOUT THE SYSTEM

The Cynthia-Coull arena wanted to upgrade its R22 refrigeration system, which had an impact on the ozone layer and global warming, with a CO₂ transcritical system with a 281 kW capacity. The piping of the brine slab was still in good condition, so it was not replaced. The arena has only one ice rink, which operates nine months per year, so work had to be done during the three-month shutdown. Several heat reclaims were included in the project: five heat reclaims for direct recovery, a CO₂/water exchanger to preheat domestic water, and a CO₂/glycol exchanger for a snow pit. One of the direct heat recovery reclaims was used to regenerate the desiccant wheel of the dehumidification station.

Carnot Refrigeration designed an ideal chiller for this type of project: a very compact rack of 4.9m by 1.7m, with a height of 1.9m. This system incorporates seven compressors, a pump for brine, a CO₂/brine exchanger, electrical panels and all the tanks and piping required for proper operation.

The installation is very simple as it consists of connecting six pipes: two for the brine, two for the CO₂ that goes and returns to the gas cooler (condenser), and the two circuits for the relief valves. In the case of Cynthia-Coull arena, ten more connecting pipes are required for the five heat reclaims. A gas cooler (condenser) was also installed to the roof, and no water tower is necessary. The piping of the system is made entirely out of steel; it can contain a pressure of 79 bar on the low-pressure side and 120 bar on the high-pressure side. During prolonged shut-downs of the system, it can keep its refrigerant charge without any other system to reduce the pressure. This feature was essential for the project, as the rink is closed for three months per year. The installation of the system was done in the allotted time, the construction of the rink was made on time, and the citizens of Longueuil were able to enjoy their ice rink as if nothing had happened.

RESULTS

Following the start-up and adjustments of the system, the manager of the arena said he had never had such high quality of ice because the ice had never been so cold and that arena had never been so warm. The temperature of the ice is stably maintained at -8°C. and the room temperature is 14°C. Energy consumption of the building was compared for the months of February and March, revealing a decrease in electrical consumption of around 23%, which represents 91,370 kWh for this specific arena, resulting in yearly savings of several thousand dollars.





CO₂ transcritical system at Les Atokas Bieler's refrigeration warehouse

INTRODUCTION

In light of the major changes the refrigeration industry has undergone in recent years, many businesses working within the field of refrigeration are forced to review their approach to refrigeration. Les Atokas Bieler, in collaboration with Carnot Refrigeration, opted for a CO₂ transcritical technology to cool its cranberries at its new refrigeration warehouse located in Saint-Louis-de-Blandford. Carnot Refrigeration, a well-established manufacturer in the field of refrigeration systems utilizing natural refrigerants, was asked to install the system, and the company managed the complete process from design to manufacturing of the system, including the installation.

ABOUT THE SYSTEM

The cranberries come directly from a flooded field to the cleaning room, and from there, go directly to the warehouse without passing through a freezing tunnel. In addition, berries enter the warehouse only once a year from late September to late October. This type of operation poses a particular challenge for system designers who must anticipate a large charge that occurs only once a year. The rest of the year, the system is used to maintain temperatures. Another particularity of this project is that the berries are very humid, which requires special evaporators and a high-performance defrosting system.

The system installed in the new berry warehouse has a capacity of 690 kW. The system is divided into three parts: the medium temperature part that includes nine semi-hermetic reciprocal compressors and two tanks; the low temperature



Visit for more information

www.carnotrefrigeration.com

Contact information

Marc-André Lesmerises, P.E.

marcandreslesmerises@carnotrefrigeration.com

ABOUT THE COMPANY

Carnot Refrigeration is a Canadian company headquartered in Quebec and established in 2008 with the goal of addressing the HVAC&R industry's failure to provide industrial and commercial clients with a thermodynamic option that would diminish environmental impact. Carnot Refrigeration makes a conscious effort to design refrigeration systems and heat pumps that cut down on the use of polluting refrigerants. It has taken the lead in its field by creating high-efficiency refrigeration systems designed by specialized engineers and manufactured in an environmentally controlled plant or at a constraint-free site. Carnot Refrigeration is experienced in meeting the needs of sports facilities (arenas), supermarkets, distribution centers and the agri-food industry.

part that includes ten semi-hermetic reciprocal compressors and two tanks; and two gas coolers including twelve fans. They system can contain 80 bar on the low pressure side and 120 bar on the high pressure side, allowing it to maintain its CO₂ refrigerant charge even if it is completely stopped.

All piping is stainless steel welded with an orbital welder. Twelve evaporators were necessary for the project, in which each coil is stainless steel designed for pressures up to 80 bar and able to handle a large quantity of water. Waste heat recovered from the system is used for hot gas defrost and sub-slab heating. For the sub-slab heating, a CO₂/glycol exchanger is installed on the system.

Carnot managed the complete installation of the refrigeration equipment for the project, from unloading equipment to welding the evaporators, and through to the positioning of the refrigeration racks. It was also required to obtain all permits and accreditations for compliance of the installation and equipment.

RESULTS

Following the start-up of the project, Carnot continues to monitor the effectiveness of its sites and to refine its remote settings. This service is highly appreciated by many customers, starting with the client who can control the temperature of its room with a simple phone call. The technician in charge of maintaining the system can also obtain important information via this service. Carnot Refrigeration has also had the chance to collect a lot of information that will be helpful for future designs.

PERFORMANCE

Although start-up of the system is recent, system performance is such that the client has acquired a second Carnot system for the expansion of its warehouse. It is certain that the effectiveness of hot gas defrost, combined with savings generated by heat recovery especially for sub-slab heating, and the quality of the installation were definitely great advantages. In addition, our customer found that he had never had such a good quality of frozen cranberries.



The implementation of the transcritical system in St-Louis-de-Blandford was a great success. Building operators are very happy and satisfied to work with this equipment. In addition to having to make a second-phase expansion of this same warehouse, we are hearing from other cranberry growers interested in acquiring such a system. We are currently experiencing the beginning of 100% transcritical refrigeration in refrigerated warehouses.





First U.S. ice rink to use sustainable CO₂ refrigeration

INTRODUCTION

HCFC-22 is frequently used as a refrigerant in ice rinks. However, as of January 1, 2020, production and importation of HCFC-22 in the U.S. will end; so ice rinks across North America will be looking for opportunities to “future proof” their facilities by moving to natural refrigerants.

Like many ice rinks around North America, the Harry J. McDonald recreational center in Anchorage, Alaska was built in the 1980s. Its aging Freon-based system was experiencing nagging refrigerant leaks, aging equipment and rising maintenance costs, necessitating a complete makeover of the facility as well as the refrigeration package and floor system.

ABOUT THE SYSTEM

The Advansor Direct Transcritical CO₂ system for ice rinks delivers superior performance — improved ice quality and pump power savings of up to 90% — compared to traditional systems. It's also environmentally friendly: CO₂ is an entirely nontoxic, environmentally safe refrigerant with excellent heat-transfer capabilities. Plus, it's a fraction of the price of traditional refrigerants.

The Hillphoenix Advansor system provides a much higher coefficient of performance (COP) than that of ammonia-calcium chloride systems. And the easily accessible heat recovery can be a heating source for the entire facility including indoor areas, locker rooms and utility water.

Hillphoenix
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Contact information

Tim Henderson

Tim.Henderson@Hillphoenix.com

ABOUT THE COMPANY

Hillphoenix designs and manufactures commercial refrigerated display cases and specialty products, refrigeration systems, integrated power distribution systems and walk-in coolers and freezers. Our environmental improvements in alternative refrigerants and energy efficiency have helped take more than 2 billion pounds of harmful emissions out of the atmosphere since 1996. Today, Hillphoenix leads the industry with its Second Nature line of alternative refrigeration systems, which includes glycol, CO₂ and ammonia-based systems.

RESULTS

The first U.S. ice rink to use sustainable CO₂ refrigeration is benefiting from lower operational costs and reduced environmental impact just two months after opening.

“We’re already seeing savings, and we’re anticipating energy savings of 25 percent to 40 percent when all the results are in,” said John Rodda, Parks & Recreation Director for Anchorage, Alaska.

The city operates the Harry J. McDonald recreational center, which reopened its ice rink to skaters and hockey teams in early January, following a nine-month renovation and installation of a carbon dioxide-based ice rink refrigeration system from Hillphoenix.

The energy-efficient CO₂ system has lowered the ice rink’s electric bills, and it also has greatly reduced spending on refrigerant. CO₂ refrigerant costs significantly less than Freon, which was used by the rink’s previous system. Equally important, moving to the newer refrigerant eliminated polluting emissions from Freon.

Rodda sees the McDonald Center ice rink as a proving ground for CO₂ as U.S. ice rinks begin to comply with upcoming federal requirements to phase out Freon. “We’ve got ice rinks calling us from all over the country to see how it’s going,” he said.

Anchorage’s early adoption of CO₂ was a well-studied decision. Parks & Recreation spent a year considering options. “We looked at all the potential non-Freon refrigerant solutions, but sooner or later, they all were likely to be affected by environmental concerns,” Rodda said. “We decided CO₂ had the most benefits.”

Parks & Recreation then considered vendors and settled on Hillphoenix because of its experience with CO₂, its reputation for stability and strong customer support; and the technology-enabled capabilities of its CO₂ refrigeration system, such as remote monitoring. Hillphoenix has installed CO₂ ice rinks in Canada and has worked with CO₂ refrigeration systems since 2005.

SUMMARY

“We are pleased to be partners with the Anchorage Parks & Recreation Department in its pioneering efforts to build more efficient and environmentally sustainable ice rinks using CO₂,” said Tim Henderson, Industrial Program Manager for Hillphoenix. “We anticipate public and private ice rinks around the country will follow Anchorage’s lead.”

The city has plans to upgrade three more ice rinks to CO₂ over the next few months, and Rodda expects those projects to yield similar results. “Trying something new was smart, environmentally friendly and efficient,” Rodda said. “From what I’ve seen in a short period of time, we made the right decision in choosing CO₂.”





GCAP - Provision of training for CO₂ and Ammonia

ABOUT THE SYSTEM

This case study shows how GCAP trains technicians in order to meet the need for regulatory-compliant, energy-efficient, and safety-conscious technicians, who benefit the industrial world by providing environmentally friendly products to the consumer in the most efficient way possible. Ammonia Operator courses follow the guidelines set forth by the Ammonia Refrigeration Task Force Guidelines (ARTG) that are published by the International Institute for Ammonia Refrigeration (IIAR).

- » **Operator I Course:** Utilizes GCAP's new operator book *"Understanding Industrial Refrigeration from the Inside Out,"* authored by Randy Williams and Jeremy Williams. This 14-chapter text, published on June 2, 2014, shows everything an operator/technician needs to know to see the refrigeration world both inside and out.
- » **Operator II Course:** Utilizes the 2012 edition of RETA's IR2 book, Industrial Refrigeration Book 2. This 10-chapter manual focuses on the troubleshooting of industrial refrigeration systems and shows an operator/technician what they need to understand when troubleshooting the system from both a hands-on and analytical perspective. Coupled with GCAP's supplemental material the course introduces operators to engineering diagrams as well as defrost systems, and cascade refrigeration focused on NH₃/CO₂ pumped and compression systems.
- » **Operator III Course:** Uses the Ammonia Refrigeration Library from IIAR and focuses on meeting the requirements an industrial facility must meet to maintain a safe facility, and on the design, safety, maintenance, and installation of a closed-circuit ammonia refrigeration system. The standards covered are ANSI-IIAR-1, ANSI-IIAR-2 including Addendum B, ANSI-IIAR-3, ANSI-IIAR-4, ANSI-IIAR-5, ANSI-IIAR-7, and Bulletins No. 107, 108, 109, 110, 111, 112, 114, & 116. In addition, the course gives a comprehensive look at a system through



Visit for more information

<http://www.ammoniatraining.com/>

Contact information

Randy Williams

ammonia@pld.com

ABOUT THE COMPANY

Since 2003, GCAP has been the premier privately owned technical school for Operators, Engineers, Process Safety Managers, and Safety Managers across the United States. Industrial refrigeration training and industrial boiler training are our primary focus. The GCAP team provides education in efficiency, safety, and compliance for the industrial ammonia refrigeration/boiler operator. Our spectrum of ammonia refrigeration and boiler technician training is tailored for everyone from the beginner with no experience to the seasoned operator. GCAP supplies training to over 700 different companies and over 1,800 students per year.

a review of plant specific P&ID's as well as ventilation calculations, and relief valve calculations to meet the applicable standards

- » **PSM/RMP Course:** Utilizes GCAP's *"Implementing Process Safety Management for Ammonia Refrigeration Systems"* 5th Edition. This 23-chapter manual is focused on PSM/RMP regulations and creating one unified program to satisfy government regulations from OSHA, EPA, and DHS. This is the first book of its kind to not only incorporate the regulations as written, but also provide guidance from the CCPS on writing a successful program. It also has a compilation of citations obtained by GCAP through the *"Freedom of Information Act"* depicting the narrative and 1B reports by OSHA inspectors on the various elements of this program for the past 3 years. Accompanying this book is a CD, which has every document a facility needs to meet these regulatory requirements.
- » **CO₂ Technician Course:** Utilizes *Natural Refrigerant CO₂* 2009 edition. This 8-module manual focusing on CO₂ refrigeration, coupled with GCAP's additional information, prepares the technician for CO₂ transcritical systems as well as NH₃/CO₂ pumped cascade systems and NH₃/CO₂ compression cascade systems.
- » **Boiler Tech 1 Course:** Uses *"High Pressure Boilers"* Fifth Edition as the primary manual. This 13 chapter handbook enables the technician to gain a knowledge and understanding of boilers including steam cycle, fuel/energy source, utility boilers, industrial boilers, co-generation, design/application and heat transfer amongst several other operations.
- » **Boiler Tech 2 Course:** Utilizes *"Stationary Engineering"* 4th edition as the primary manual with supporting material from GCAP and several burner manufacturers. This 15-chapter handbook focuses on the combustion cycle. The seminar the technician shows the technician how to monitor and test combustion for the reduction of emissions NOX, O₂ trimming from a computer monitoring-system or hand held- devices, carbon dioxide formation and release, carbon monoxide generation, thermal heat transfer, and flame temperature.



RESULTS

GCAP's Mission Statement: *"Enhance the technology, efficiency, safety and educate the industrial technician through commitment"* has proven that with proper trained technicians/operators/engineers the Industrial/ Commercial World can have safe, efficient, and environmentally secure systems not only now but in the future.



Meet the authors



Marc Chasserot

Publisher / Managing
Director

Marc Chasserot is the Managing Director of shecco, with over 10 years' experience in the HVAC&R sector. In 2006 he founded the industry leading website for CO₂ cooling and heating experts worldwide: www.R744.com. This was followed by three platforms for hydrocarbons, water and ammonia. He has chaired and organized numerous international workshops for policy and industry experts to discuss how to bring natural refrigerants faster to market, known as 'ATMosphere'.



Klára Skačánová

Deputy Manager,
Market Development

Klára holds a Master's degree in International Relations from the University of Economics in Bratislava, Slovakia. She is an expert on following legislative developments with an impact on the heating and cooling industry at national, European and international levels, and informs decision-makers about the latest trends in the field of natural refrigerants.



Elke Milner

Coordinator,
e-Marketing

Elke holds a Master's degree in Political Science with a concentration in European Union Economic and Social Policy from James Madison University. She works within shecco's Media team to disseminate valuable information and analysis to further the reach of natural refrigerants in HVAC&R industries.



Nina Masson

Lead Author / Deputy
Managing Director

Nina holds two Master's degrees in Business Management and in Environmental Management. For the last 8 years, she has been working in the field of environmental technologies, where she has developed special expertise on natural refrigerants. Today, she is active in market development and consultancy services, as well as special projects and publications. She has been drafting and supervising global studies on behalf of United Nations agencies, as well as serving as an expert for EU and UN projects.



Robert Davidson

Analyst,
Market Development

Robert Davidson is the holder of a Master's degree in Development Economics from the School of Oriental and African Studies, London. An interest in the future of energy led him to shecco where he works as an Analyst in shecco's business development department. He works in identifying trends in natural refrigerants and helping clients optimize their strategy in the HVAC&R market.



Michael Garry

North American Editor
of Accelerate America

Michael Garry is a business journalist with a 30-year track record. Most recently, he led the coverage of sustainability, technology and logistics at Supermarket News for more than 11 years. He is well known among retailers, suppliers, technology vendors and trade groups throughout the North American food retailing and consumer goods industries.



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Email us at

research@shecco.com

Talk to us on the phone

(202) 657-6164

Our mailing address

shecco America 570 Seventh Avenue, 18th Floor, New York,
NY 10018 - USA

shecco Europe Rue Royale 15, 1000 Brussels, Belgium

shecco Japan Office 20 EGG JAPAN Shin-Marunouchi Building 10F Marunouchi
1-5-1, Chiyoda-ku 100-6590, Tokyo, Japan

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