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2013: NATURAL REFRIGERANTS MARKET GROWTH FOR NORTH AMERICA

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MARKET GROWTH FOR NORTH AMERICA

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MARKET GROWTH FOR NORTH AMERICA

MARC CHASSEROT
Publisher and Managing Director of shecco

A SHORT MESSAGE

shecco has been working at the forefront of natural refrigerant based heating and cooling applications for 10+ years now. We are active worldwide and see a growing need for data, trend analysis, and case studies from companies working with or looking to work with natural refrigerants. The market potential for natural refrigerants in North America is rising fast, especially as the business case becomes clearer for more and more companies.

We share information and best practices through our industry platforms: R744.com, hydrocarbons21.com, ammonia21.com and R718.com. We bring experts together to discuss the future of natural refrigerants through our interactive workshops known as ATMOsphere, including the annual ATMOsphere America.

Today we publish an 'industry first' GUIDE to Natural Refrigerants – Market Growth for North America. We have been collecting data from hundreds of experts over the last year. We have analyzed trends, identified technology case studies, presented survey results to measure market outlook and much more.

In 2013, we will continue to discuss within industry, collect data, present trends and document progress of market penetration of natural refrigerants across North America, with the objective of updating this GUIDE one year from now.

Happy reading

ABOUT THIS GUIDE

A SHORT OVERVIEW

More than one in four respondents to an industry survey conducted for this GUIDE believe that North America has the potential to become a world leader in natural refrigerant technology. In fact, North America presents one of the largest immediate market opportunities for natural refrigerants (NR), both because of the size of its internal market, and also because of the leadership role it can play, providing an example which other developed and developing countries can follow. However, besides the dominant use of ammonia refrigerant in industrial refrigeration, the North American market has remained one of largely untapped potential for HFC-free solutions. Since the use of hydrocarbons in small applications was recently approved by the US Environmental Protection Agency, their widespread adoption now largely depends on setting the right course in the field of standards, refining and tailoring regulations to avoid burdens and barriers, as well as on proactive end-use industry leaders investing in natural refrigerant technology. The same is true for CO_2 refrigerant which is expected to make inroads in the commercial refrigeration and hot water heating markets as soon as ongoing trials have proved its financial viability, and regulatory conditions have become more favorable.

At a time when the overall economic climate has toughened, business choices have become harder, and solutions that are advantages from both an economic and a long-term environmental perspective need to be found. The fact that natural refrigerants – including ammonia, carbon dioxide, hydrocarbons, water, and air – can be viable alternatives, and in some cases are already mainstream solutions, is at the core of this GUIDE. While the environmental and technological benefits of these substances are now being acknowledged by a growing number of business leaders in the supply and the end-use industry, this GUIDE is the first-ever publication to present an overview of the market potential for natural refrigerants. It summarizes state-of-the art technology, captures the industry's and the end-users' views, brings together scattered information on best practice in the form of case studies, and explains the use potential of natural refrigerants. More than 550 North American industry experts have co-authored this publication, adding their views by taking part in an industry survey assessing several crucial issues such as familiarity levels with NRs, current and future use of NR products and services, as well as overall purchasing criteria for end-users and how these criteria match with the strengths and weaknesses of non-synthetic working fluids. Industry experts also predict that the market growth of NR solutions will continue in commercial and light-commercial refrigeration, in industrial and residential air-conditioning, and in industrial refrigeration in the coming years.

Chapter 1 – a User's Guide to Natural Refrigerants in North America – briefly summarizes the characteristics of the "natural five" (ammonia, carbon dioxide, hydrocarbons, water, and air), while depicting their use in four "ecosystems": The Food Chain, City & Buildings, Transport, and Industry & Special Applications. The chapter concludes with an outlook on the adoption potential of natural working fluids in different world regions, highlighting the application potential of NR technology outside the North American market and, thereby, drawing attention to more business opportunities.

NINA MASSON

Head of Market Research

Chapter 2 – Emerging Markets in North America – examines two selected industry sectors that are expected to show strong growth in the coming years. The CO_2 supermarket maps depict, for both Canada and the US, where secondary, cascade, and transcritical CO_2 refrigerant-based commercial refrigeration systems have already been adopted or are planned to be adopted. A light-commercial refrigeration map provides an overview of leading consumer good brands driving the adoption of hydrocarbons and carbon dioxide refrigerants in Canada, Mexico, and the US.

Chapter 3 – Policies & Case Studies – first explains how voluntary industry schemes, safety and building standards and regulation can influence the use of natural refrigerants in the fields of training & know-how, technology & safety, economy & costs, and awareness & psychology. The chapter closes with case studies; evident examples of installations where natural refrigerants make sense both from a business and a technology perspective.

Chapter 4 – End-User Views & Industry Survey – features recommendations from leading food retailers and consumer goods brands on how to bring natural refrigerants faster to the North American market. Results from a survey of 556 HVAC&R industry experts and end-users highlight the use of NR products and services today and in the future, the lack of awareness impeding a more rapid market uptake, the competitiveness of NR solutions versus traditional refrigerants, their compatibility with end-users' purchasing criteria, and the impact of current business and policy climates on market developments. The section closes with market forecasts for 2015 and 2020 for various industry sectors.

Business Directory – the GUIDE concludes with a directory of North American-based companies, associations, end users, and international organizations already involved in natural refrigerants today.

This GUIDE puts forth evidence that there is a market for more sustainable refrigerant solutions, and that it is growing. It also draws attention to the fact that challenges remain for a broader acceptance of alternative refrigerants. As one of the strongest drivers of adoption of NRs, a solid information base about the existence, properties, and usability of HFC-free solutions is paramount to making well-informed choices. I hope that this GUIDE can be one such tool for gathering relevant facts needed to evaluate the business case for natural refrigerants.

USER'S GUIDE TO NATURAL REFRIGERANTS IN NORTH AMERICA

ABOUT NATURAL REFRIGERANTS

The "natural five," air, ammonia, carbon dioxide, hydrocarbons, and water, have distinct characteristics that make them viable options for a wide range of heating and cooling applications, today and tomorrow. See a short overview of the most commonly used natural working fluids and their chemical, physical, technical, and environmental properties on...

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NATURAL REFRIGERANT ECOSYSTEMS: NORTH AMERICA

Across North America, carbon dioxide, ammonia, the group of hydrocarbons, and water are already widely used as energy-efficient refrigerants in four main sectors: Transport, Cities & Buildings, the Food Chain, and Industry & Special Applications. See a visual presentation of selected air-conditioning, heating, and refrigeration end-uses in these four "ecosystems", starting from...

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NATURAL REFRIGERANT ECOSYSTEMS: A GLOBAL PERSPECTIVE

What pointers could North American stakeholders gain from other world regions where ammonia, carbon dioxide, the group of hydrocarbons, water, and air are used in applications not currently utlilized in Canada, Mexico or the US? Find out more about applications using HFC-free refrigerants that have been widely adopted or are being thoroughly investigated in other world regions...

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ABOUT NATURAL REFRIGERANTS

AN OVERVIEW

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, not naturally occurring in the environment. The precision of the term "natural refrigerants" is sometimes debated, given that, to be used as refrigerants, ammonia, carbon dioxide, and hydrocarbons also undergo an industrial purification and manufacturing process. However, today there is a well-established distinction between substances whose chemical properties and safety aspects have been studied in their entirety, and those fluorinated gases which, given their chemical complexity and comparatively short period of usage, have confirmed and/or have unknown negative effects on ozone depletion, global warming and ecological safety, 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), iso-butane (R600a), and propylene, also know 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 and air are also used, to a lesser extent, for example in adsorption chillers and deep-freezing applications. In addition to their wide availability, their non-toxicity, non-flammability, and their unbeatable environmental credentials have, once again, shifted water and air 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 nonflammable. 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 by-product 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, it 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 alkylene 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 and flammability. 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.

The additional safety equipment required will obviously increase costs; however, manufacturers claim that operational energy and maintenance savings potentially outweigh the higher initial outlay in the long run.

HYDROCARBONS (ODP= 0; GWP< 4)

With zero ozone-depleting characteristics and an ultra-low global warming impact, the group of hydrocarbons (HCs) does 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 some modifications will probably be required to ensure compatibility. Lubricant compatibility and the issues associated with hydrocarbons' flammability will 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 anti-foaming 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 the cheapest refrigerant.

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 adsorber.

From an environmental and thermodynamic point of view, water is an ideal refrigerant for applications above 0°C. R718 has a higher latent heat of evaporation (2,270kJ/ 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 for 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 last century.

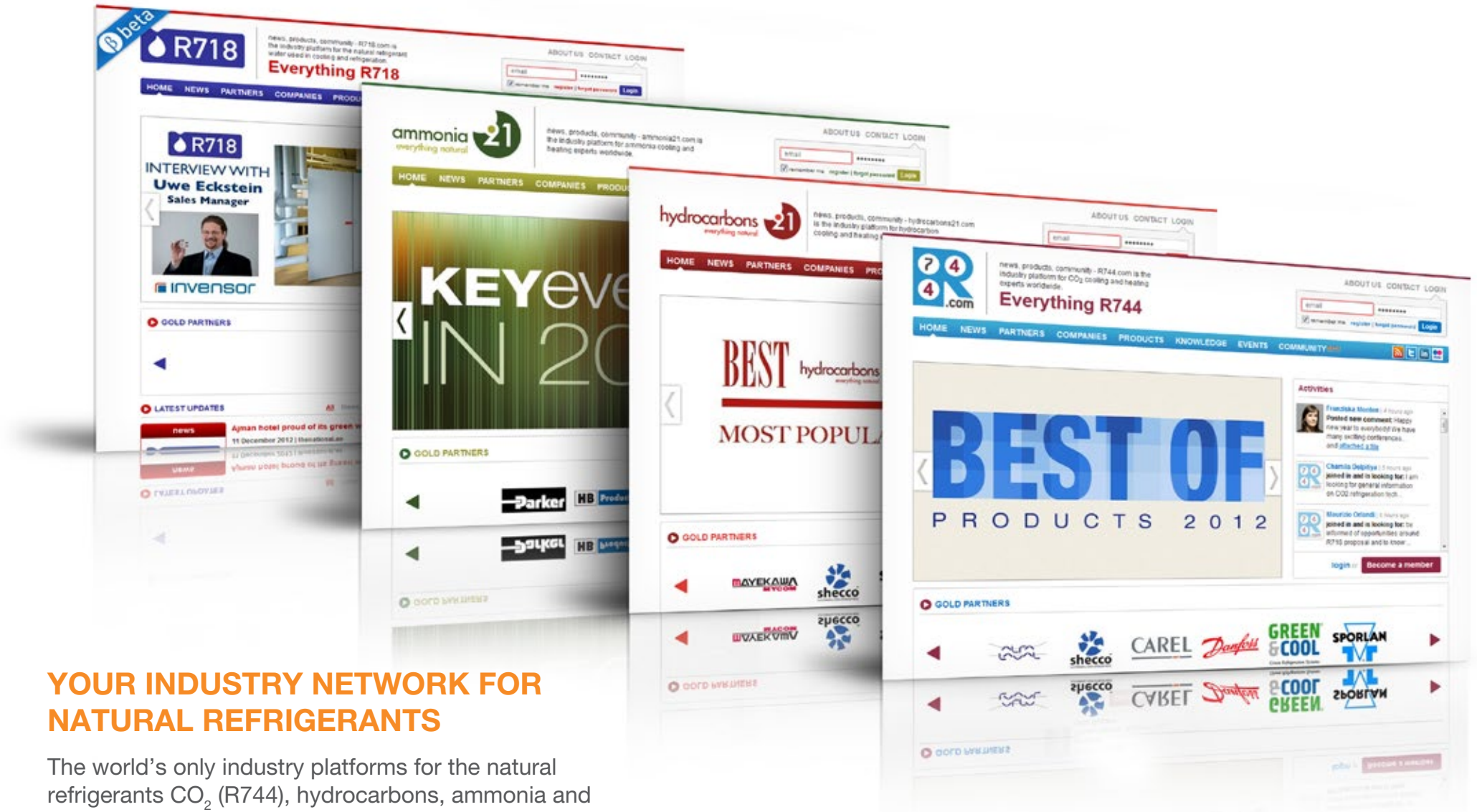
Air cycle refrigeration works on the reverse Brayton or Joule cycle. Air as a refrigerant does not undergo phase change (condensation/evaporation) at the temperature levels encountered in conventional refrigeration applications. The COP value of air is low because of its light weight, but air cycle cooling systems can provide relatively high temperature heat recovery without the efficiency set back 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.

NATURAL REFRIGERANT CHARACTERISTICS

REFRIGERANT	REFRIGERANT NUMBER	CHEMICAL FORMULA	GWP (100 YEARS)	ODP	NORMAL BOILING POINT (˚C)	CRITICAL TEMPERATURE (˚C)	CRITICAL PRESSURE (BAR)	SAFETY GROUP	MOLECULAR WEIGHT (G/MOL)
Ammonia	R717	NH_3	0	0	-33.3	132.4	114.2	B2	17.03
Carbon dioxide	R744	CO_2	1	0	-78	31.4	73.8	A1	44.0
Propane	R290	C_3H_8	3.3	0	-42.1	96.7	42.5	A3	44.10
Isobutane	R600a	C_4H_{10}	4	0	-11.8	134.7	36.48	A3	58.12
Propylene	R1270	C_3H_6	1.8	0	-48	91	46.1	A3	42.08
Water	R718	H_2O	0	0	100	373.9	217.7	A1	18.0
Air	R729	-	0	0	- 192.97	-	-	-	28.97



YOUR INDUSTRY NETWORK FOR NATURAL REFRIGERANTS

The world's only industry platforms for the natural refrigerants CO_2 (R744), hydrocarbons, ammonia and H_2O (R718). Your online resource for products, news, knowledge, events, experts, and more. Visit us at:

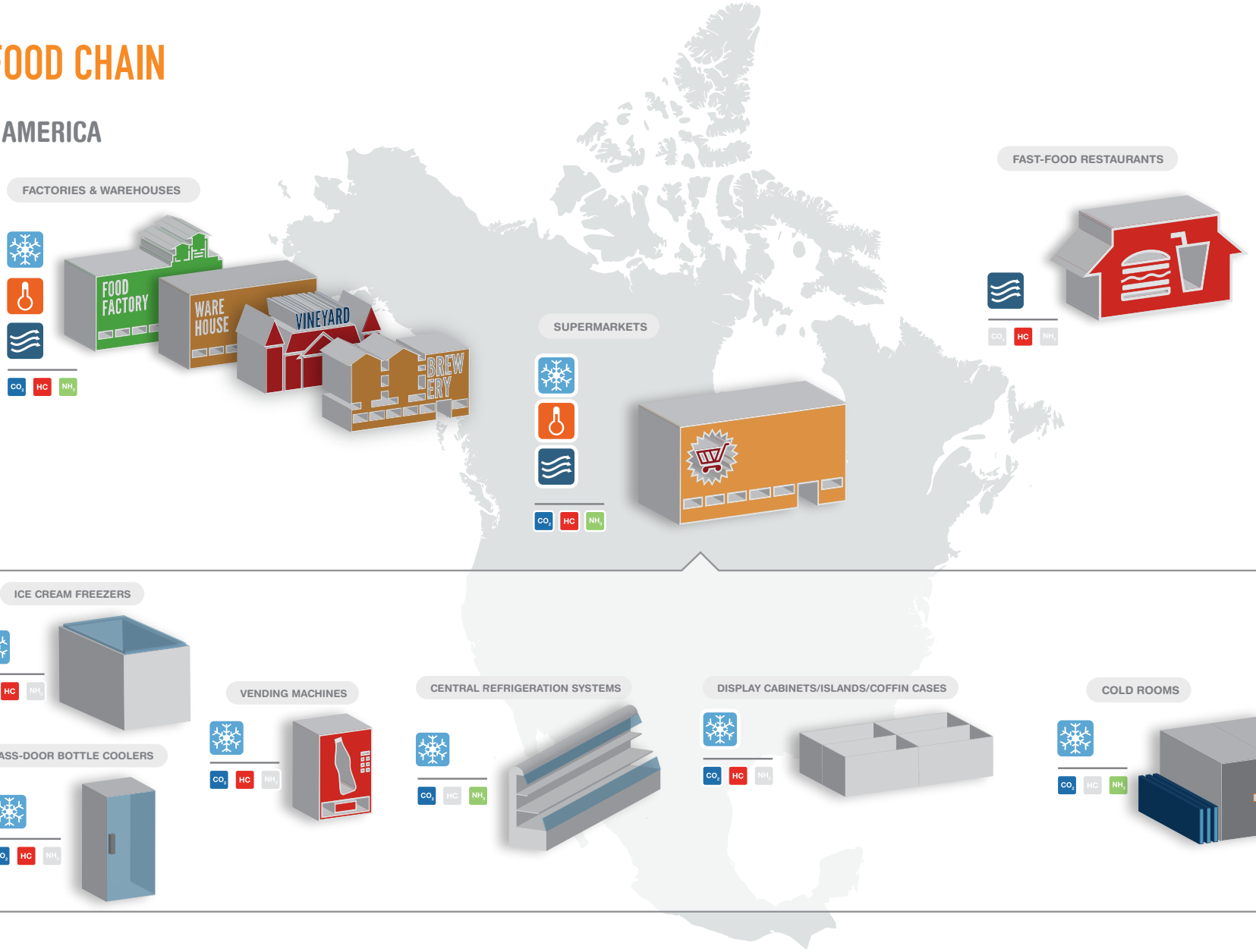
www.R744.com
www.hydrocarbons21.com
www.ammonia21.com
www.R718.com

NATURAL REFRIGERANT ECOSYSTEMS: NORTH AMERICA

In Canada, Mexico, and the USA natural refrigerants are used in a variety of applications. Using an "ecosystem" approach; representative types of buildings, facilities, installations; and vehicles using HFC-free refrigerants are grouped together to provide a visual overview of key end-use applications of natural working fluids in the North American market. The four different “ecosystems” presented are: Transport, Cities & Buildings, the Food Chain, and Industry & Special Applications. Although the applications depicted do not represent an exhaustive list of current natural refrigerant uses, they nevertheless present an extensive list of available technologies using ammonia, carbon dioxide, the group of hydrocarbons, and water.

THE FOOD CHAIN

NORTH AMERICA



NH_3 Ammonia | CO_2 Carbon Dioxide | HC Hydrocarbons | Refrigeration | Heating | Air Conditioning

THE FOOD CHAIN

In the last two years, significant change has occurred in the North American cold chain with an emphasis toward improved refrigeration systems and efficiency. The required replacement of R-22 has resulted in a switch to ammonia or CO_2, or ammonia/CO_2 cascade systems.

FOOD PROCESSING

NH_3: Ammonia has become one of the most commonly used refrigerants for the food processing industries and can be found in fish, meat, and poultry processing plants, confectionary and bakery facilities, fresh milk and dairy production plants, as well as wineries and breweries. It is widely used because it produces the greatest net refrigerating effect (btu/lb) and the lowest brake horsepower per ton of refrigeration (BHP/TR) of any industrial refrigerant.

For example, Baltimore-based Northeast Foods is a commercial baking powerhouse, supplying McDonald's with most of their hamburger buns. The company's Clayton facility uses an ammonia refrigeration plant at its 103,000 sq. ft. (9,569 m2) site that includes a 13,500 sq. ft. (1,254 m^2) freezer at -10°F (-12°C). The ammonia system in its freezer is used to chill glycol for process equipment, mixers, and ingredient cooling, eliminating separate equipment for the process chilling. Kleinpeter Farms Dairy uses an ammonia refrigeration system and captures the heat from the refrigeration system to heat water used for cleaning and pasteurization purposes. In Oklahoma, Sigma Alimentos (Sigma) has an ammonia refrigerated food processing plant that produces a range of Mexican-style hams, hot dog sausages, sliced meat, and cold cuts at its Seminole facility. In addition to its use in refrigeration systems, ammonia heat pumps are another technology gaining ground. The Budweiser Anheuser-Busch Brewery in St. Louis, one of the first to commit to the development of mechanical refrigeration using large steam engine driven ammonia compressors, now has an ammonia refrigeration system rated at 18,000 tons of refrigeration. MillerCoors has also installed a new ammonia compressor at its Milwaukee brewery to help achieve its stated goal of reducing energy use by 15% by 2015. The ammonia refrigeration system contributes to annual energy savings of 3.3 million kilowatt hours. At MillerCoors Texas brewery, an upgraded ammonia refrigeration system has eliminated energy-wasting pressure drops and ensures that the evaporative condenser is used effectively. This has reduced annual energy use by 3.6%. As an addition to an existing ammonia refrigeration system, American multinational Kraft Foods uses an ammonia heat pump system to capture rejected heat and reuse it to provide water heating at a food processing facility in Davenport, Iowa. This has reduced Kraft's heating energy costs by 61%, reduced site energy consumption for heating by more than 79%, reduced condenser water consumption by 15 million gallons (57 million liters) per year, and delivered a host of additional operation and maintenance savings.

H_2O: Exhaust heat from electricity generation is used to drive an absorption chiller for air-conditioning of closed loop food production facility, The Plant, in Chicago.

CO_2: Although used to a lesser extent, CO_2 heating and cooling systems are gaining ground in the food processing industries. In the world famous Napa Valley, California, Wine producer Somerston Wine Co. installed an integrated CO_2 heating and cooling system for glycol cooling and hot water heating. The first such system to be implemented in a winery, it is comprised of four elements: a CO_2 refrigerant heat pump, a hybrid adiabatic fluid cooler that replaces the traditional cooling tower, a glycol warming system for tank and barrel room heating, and a high efficiency glycol chiller for additional tank and barrel room cooling. The installed system had a 3.5-year payback.

Midwestern commercial bakery Country Maid also installed a transcritical CO_2 heat pump system that simultaneously produces high temperature hot water for washing baking equipment and cool, comfortable air-conditioning for employees. It is expected that the heat pump will yield electrical energy savings of 30% compared to traditional energy consumption and a payback within 3.5 years.

In Canada, CO_2 heat pumps have been integrated in a dairy/cheese plant in Québec. The Fromagerie Polyethnique / Fromagerie Fritz Kaiser dairy/cheese plant saves an estimated 28,000 gallons (105,000 liters) of propane fuel per year on account of the CO_2 heat pump. One of the main benefits of the CO_2 heat pump unit is that it can achieve the high temperatures needed during the production process (up to 194°F/90°C). The payback period for the project was estimated at 4-5 years, but thanks to the energy efficiency incentives of the Québec government the payback period was reduced to two years.

FOOD STORAGE & DISTRIBUTION

NH_3: Across North America, the demand for convenience foods has resulted in the construction of millions of square feet of cold storage facilities. In these facilities, the freezers and coolers, more often than not, use ammonia refrigeration systems to control temperatures to maintain product quality and freshness.

Examples include the largest cold storage distribution center in the USA, the 840,000 sq. ft. (78,000 m^2) Black Mountain facility in North Carolina and, in Canada, Sobey's 147,000 sq. ft. (13,650 m^2) refrigerated distribution center in Trois-Rivieres, Quebec. The center's use of an ammonia central chiller and heat recovery on the condenser side of the chiller for space heating won the ASHRAE 2010 Technology Award. Other examples of ammonia using

systems are Ahold USA's Giant Distribution Center in Carlisle, Pennsylvania, which operates on a two-temperature, single stage ammonia refrigeration system, as well as Fresh & Easy's 53,000 sq. ft. (4,942m^2) Riverside Distribution Center for meat & poultry processing and distribution in California, which has a two-stage pumped re-circulated ammonia system serving a multitude of 30 to 40°F (-1 to -4°C) processing rooms, -30°F (-1°C) spiral blast freezers, and other processing equipment.

In recent years, facilities adopting ammonia refrigeration have begun to receive the recognition of US. Green Building Council (USGBC), the leading evaluator of environmentally sustainable buildings in the US In North America, Canada's first refrigerated distribution center with ammonia coolant in its mechanical room was recognized by the USGBC with the LEED Gold certification. United Natural Foods' four distribution centers in Washington, New York, Providence, and Lancaster were also awarded LEED Gold and Silver certifications.

NH_3/CO_2: United States Cold Storage is pioneering a new CO_2 refrigeration technology used in food storage facilities in Indiana, California, Pennsylvania, and Florida. The system uses ammonia and CO_2 in a cascade system that allows for lower operating pressures and confines ammonia to the machine room only.

Canadian food distribution center Flanagan's also combined CO_2 and ammonia in its warehouse expansion project, eliminating F- gases from its site. The 199,000 sq. ft. (18,500m^2) facility uses a dual temperature ammonia/CO_2 brine packaged system, able to efficiently store 200 tons of refrigeration at temperatures ranging from 59° to 18.4°F (-15 to -28°C).

HC: Fruit growing companies such as Lake Breeze in the US and Mansfield's Fruit Farms both have both reported positive experiences after using the SRS (Secondary Refrigerant Systems) incorporated in R1270 chillers.

SUPERMARKETS

CO_2: There are over 36,500 supermarkets[1] in the US, and in 2009, the US EPA approved the use of CO_2 in food retail refrigeration and cold storage warehouses. Shortly thereafter, US food retailers began making significant investments in CO_2 refrigeration. Retailers that opted for CO_2 include the Sprouts Farmers Market Westlake Village Store, which employs a CO_2 cascade system for both low temperature and medium temperature applications. ShopRite, a small independent retailer, has a store in the Hatfield Pointe Shopping Center in Hatfield, Pennsylvania, that combines a medium temperature secondary coolant system using glycol and a low temperature direct expansion cascade system using CO_2 as a refrigerant. Wegman's has at least two stores that use CO_2 as a secondary refrigerant. Giant (Ahold US) uses CO_2 for its primary refrigeration and propylene glycol as a secondary refrigerant in its Arlington, Virginia store.

In Canada, CO_2 transcritical is rapidly becoming an established commercial refrigeration technology. Sobey's has already installed 36 CO_2 transcritical systems. At the Maple leaf Gardens store, Loblaws used a CO_2 refrigeration system, which makes use of the reclaimed energy from the refrigeration system to heat the underground parking garage. The system enabled Loblaws to reduce the total amount of refrigerant leaks by 9.7% in 2011. In the US, Hannaford Bros., Fresh & Easy Neighborhood Market, and Whole Foods Market are planning to install CO_2 transcritical systems in the near future. Delhaize US applied CO_2 secondary systems and CO_2 cascade systems in 5 stores. Two stores received a Gold Certification from the GreenChill (EPA) alliance.

There are three main types of CO_2 system that can be used in commercial refrigeration:

- CO_2 secondary loop system: in these installations pumps circulate liquid CO_2 throughout the display cases at the required case temperature. The systems can be used for both low and medium temperature applications.
- CO_2 cascade subcritical direct expansion systems: with this technology, an HFC centralized DX system is used for MT loads and the LT system has a separate circuit that discharges its heat into the suction stage of the MT system. These installations use compressors to produce the desired saturated suction and reject heat to the DX high side rack. They are typically used only in low temperature applications.
- CO_2 booster transcritical system: this model uses R744 (CO_2) in both the MT and LT systems. In these systems the same evaporation and compression occur as in DX operation but instead of condensing superheated gas into a liquid, the system cools a superheated, supercritical gas into a cooler supercritical gas. Moreover, the transcritical system DX cycle directly feeds the low temperature discharge into the suction of the medium temperature, helping to improve efficiency.

CO_2 systems benefit from the fact that the lines required for CO_2 transport are typically one to two sizes smaller than traditional DX piping systems, reducing the weight of installed copper lines by 50% or more and reducing installation costs. It should also be noted that for hybrid CO_2 systems there is a general trend towards using lower global warming potential (GWP) fluids as the second refrigerant.

NH_3/CO_2: Ammonia has already been accepted under the EPA 's SNAP Program as an alternative primary refrigerant in secondary loop commercial applications.

1 "EIA Global (n.d) New Report Highlights Climate Friendly Supermarket Refrigerant Technologies to Replace HFC "Super Greenhouse Gases, Environmental Investigation Agency (EIA) Global [ONLINE] Available at: http://www.eia-global.org/PDF/Supermarket_Report_Release.pdf [Accessed 14 January 2013]"

Despite the toxicity and liability concerns over the use of ammonia in the food industry, several large retail chains in North America are using ammonia cascade systems. This is due to the significant improvements in system design, reduced charge sizes, and better safety features. SUPERVALU installed an ammonia primary system and a CO_2 cascade system in its Carpinteria, Albertson's store in California. Also in the US, the Defense Commissary Agency is considering using an NH_3/CO_2 cascade system at the Lackland Air Force Base Commissary in Texas, which would result in 8% energy savings, reduce leakage by 25%, and eliminate HFCs.

NH_3/CO_2 cascade systems are believed to have a more stable performance than CO_2 transcritical systems in warmer climates. Such cascade systems both reduce the HFC charge and help retailers reduce energy consumption and carbon emissions.

HC: In North America, in particular in the United States, the use of hydrocarbons is limited due to the safety concerns associated with charge sizes greater than 150g. Hydrocarbons are not approved as an acceptable substitute for large retail food refrigeration systems under EPA's SNAP Program. Nevertheless, examples of hydrocarbon refrigerant use in supermarkets do exist. A propylene glycol based heat-transfer fluid is being used in a refrigeration system for meat and dairy products, and other medium-temperature foods in Wal-Mart's experimental Supercenter store in Aurora, Colorado. Unlike traditional systems that require a separate motor for each cold case, the new system employs "secondary loop refrigeration," which requires only one motor. This setup, which is made possible by the unique properties of the heat-transfer fluid, has reduced energy consumption by up to 24%.

LIGHT-COMMERCIAL SYSTEMS: DISPLAY CABINETS, ICE CREAM FREEZERS AND VENDING MACHINES

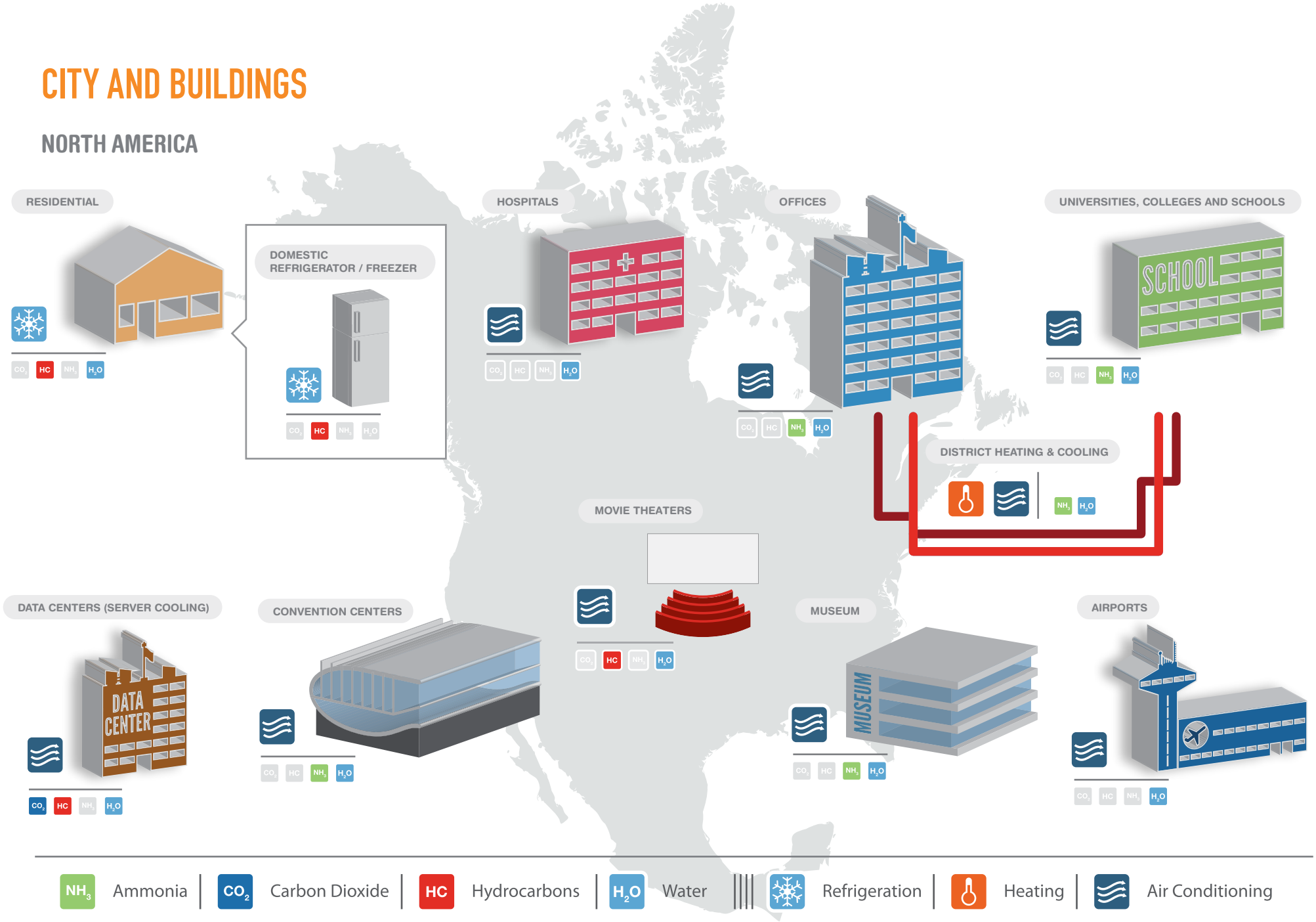
HC: : In Canada, Ben & Jerry's stores received federal approval in 2008 to use hydrocarbon propane freezers which were also installed in the US in successful pilot test.

FAST FOOD RESTAURANTS & COMMERCIAL KITCHENS

HC: In Mexico, Pizza Hut has installed a hydrocarbon air conditioning system in one of their restaurants.

CITY AND BUILDINGS

NORTH AMERICA



CITY AND BUILDINGS

RESIDENTIAL

In North America, due to concerns of flammability, HC domestic refrigerators were on regulatory ice for years, making the US the only large market not to have adopted the widespread solution. However, the situation for hydrocarbons fundamentally changed in 2011, when the US EPA, under the Significant New alternatives Policy (SNAP) program, approved three hydrocarbon refrigerants R290, R600a, and R441A (a hydrocarbons blend also known as HCR188C) as acceptable substitutes in household and small commercial, stand-alone refrigerators and freezers.

Key industry stakeholders in North America believe that household refrigerators with hydrocarbons will slowly take over the market. In 2012, GE introduced the first isobutene refrigerator, under the brand name Monogram, to the US market. In Mexico, Bosch Siemens Hausgeräte BSH Mexico has begun marketing hydrocarbon refrigerators in cooperation with local retailer Sears Mexico.

PUBLIC & COMMERCIAL BUILDINGS: AIRPORTS, HOSPITALS, UNIVERSITIES, GOVERNMENT AND HISTORIC BUILDINGS, HOTELS, SHOPPING MALLS

H_2O: Among the natural refrigerant technologies used for building air conditioners in the US, perhaps the most popular is absorption. For example, the Motefiore Medical Center in Bronx, New York, uses two double-effect, high-pressure steam absorption chillers, one at 800 tons and another at 1,000 tons. These units cool 400,000 sq. ft. of the center, including 21 operating rooms, all of the intensive-care units, and approximately 450 beds. According to facility managers, energy costs are approximately half of what they had been paying for the operation of two 750 ton electric chillers.

The City of Hope chiller plant in California utilizes steam power and natural gas (indirectly) to power one 2,000-ton double-effect absorption chiller to provide cooling to the health care facility. Absorption chillers are used in other medical facilities across the US, for instance in Jamaica Hospital (NY), Loyola Medical Centre (IL), St. Luke's Hospital (OH), and Scripps Clinic (CA).

In Canada, solar thermal powered absorption chillers with a cooling capacity of 105kW, a 3,000 gallon (11,356 liters) storage tank, and w162 solar thermal collectors were installed in a recently renovated retirement home, Oxford Gardens, in Ontario. This installation saved 50,000 kW of electricity during the first full cooling season and received the 2012 Intersolar North America Award.

Sorption technology is often used in combination with gas turbines in Combined Cooling, Heating and Power (CCHP) projects, where exhaust heat from electricity generation is utilized to drive a thermochemical cycle that produces chilled water for air-conditioning. Viking Yachts' headquarter offices use CCHP systems with absorption chillers in their new power plant in New Jersey. Cogeneration with an adsorption chiller, powered by exhaust heat, was installed in the LEED Platinum recognized renovated offices of Perkins+Will in Atlanta.

Absorption chillers are increasingly popular in data centers. For example, DataGryd designed a cogeneration facility for 240,000 sq. ft. (22,297m^2) 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%. Cogeneration of power and cooling with gas turbines and absorption chillers providing 300 tons of chilled water will be installed by October 2013 in Pennsylvania State Employees Credit Union.

Sorption technology for air-conditioning and also for heating has been installed in many academic institutions. For example, Carnegie Mellon University in Pittsburgh uses solar thermal and bio-diesel fuel, two renewable sources of energy, to drive a pair of 16 kW absorption chillers/heaters. Natural gas or solar thermal powered absorption chillers can also be found in the Desert Hill High School in Arizona and Columbia University Medical Center in New York.

Absorption and adsorption chillers are used in other facilities such as hotels, museums, movie theaters, convention centers, and airports. The US Air Terminal at LaGuardia International Airport, New York City, is heated and cooled by three natural-gas-powered 500 ton absorption chiller/heaters. Based on previous utility records, the plant has been shown to save 40% in energy costs. By using one system to perform both heating and cooling, the system actually saves space and simplifies maintenance procedures.

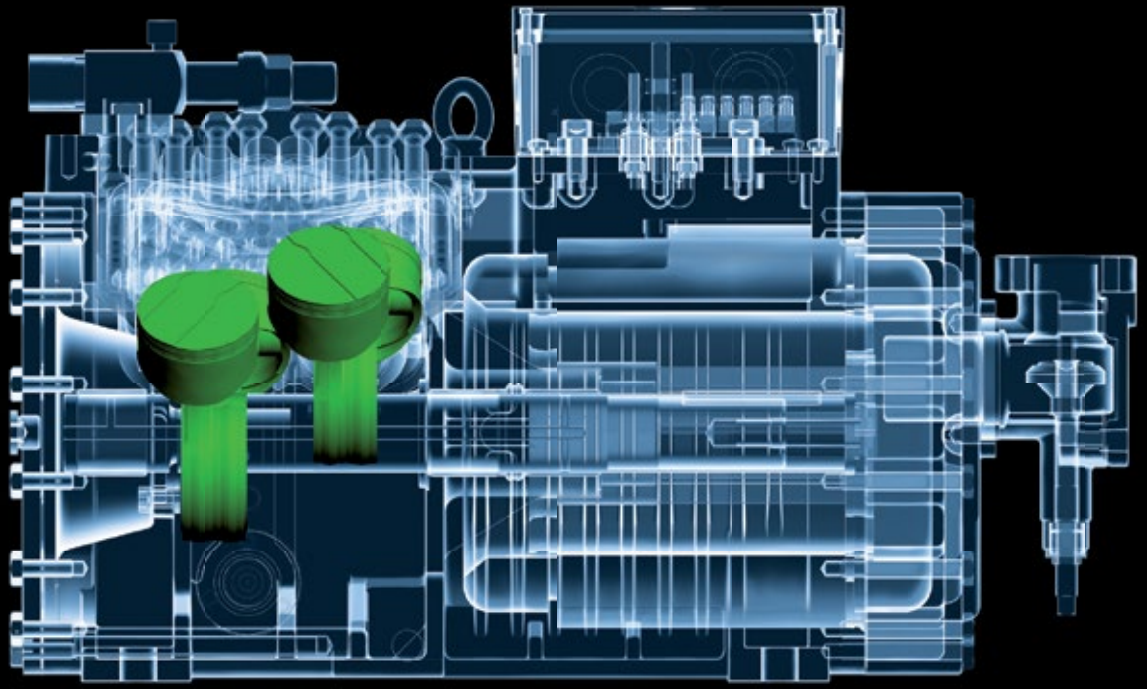
The Steinway & Sons piano factory in Queens, New York, installed a field of parabolic solar panels that heat a mixture of water and glycol to 350 degrees and pump water into an 80 ton double-effect absorption chiller.

Advanced absorption technology can offer additional advantages, beyond those achievable with the currently manufactured single effect and double-effect absorption chiller products, for most applications. Recently developed triple-effect chillers will add significant additional cooling capacity, using recovered heat for large commercial building applications.

HC: In Mexico, Cinemas, such as Cinépolis, a bowling alley called Bolerama TEC, and Telmex, one of the country's largest telecom companies, have all invested in hydrocarbon refrigerants.

DISTRICT HEATING AND COOLING

NH_3: Beneath the streets of downtown Chicago, a network of pipes distributing chilled water forms part of one of the world's largest interconnected district cooling systems. Ammonia chillers, ice tanks, and river water chillers provide cooling for air conditioning in buildings, removing on peak grid stress. Chicago's thermal district cooling system serves around a hundred buildings and upwards of 45 million sq. ft. (4 million m^2) of space. In the basement of the Blue Cross/Blue Shield headquarters on Randolph Street in Illinois, you can find P3, housing three large ice tanks and an ammonia chilling plant. The ammonia chillers and ice tanks replaced a previous 30,000-ton R22 plant.



OCTAGON CO_2

CO_2 AS A REFRIGERANT?
ABSOLUTELY!

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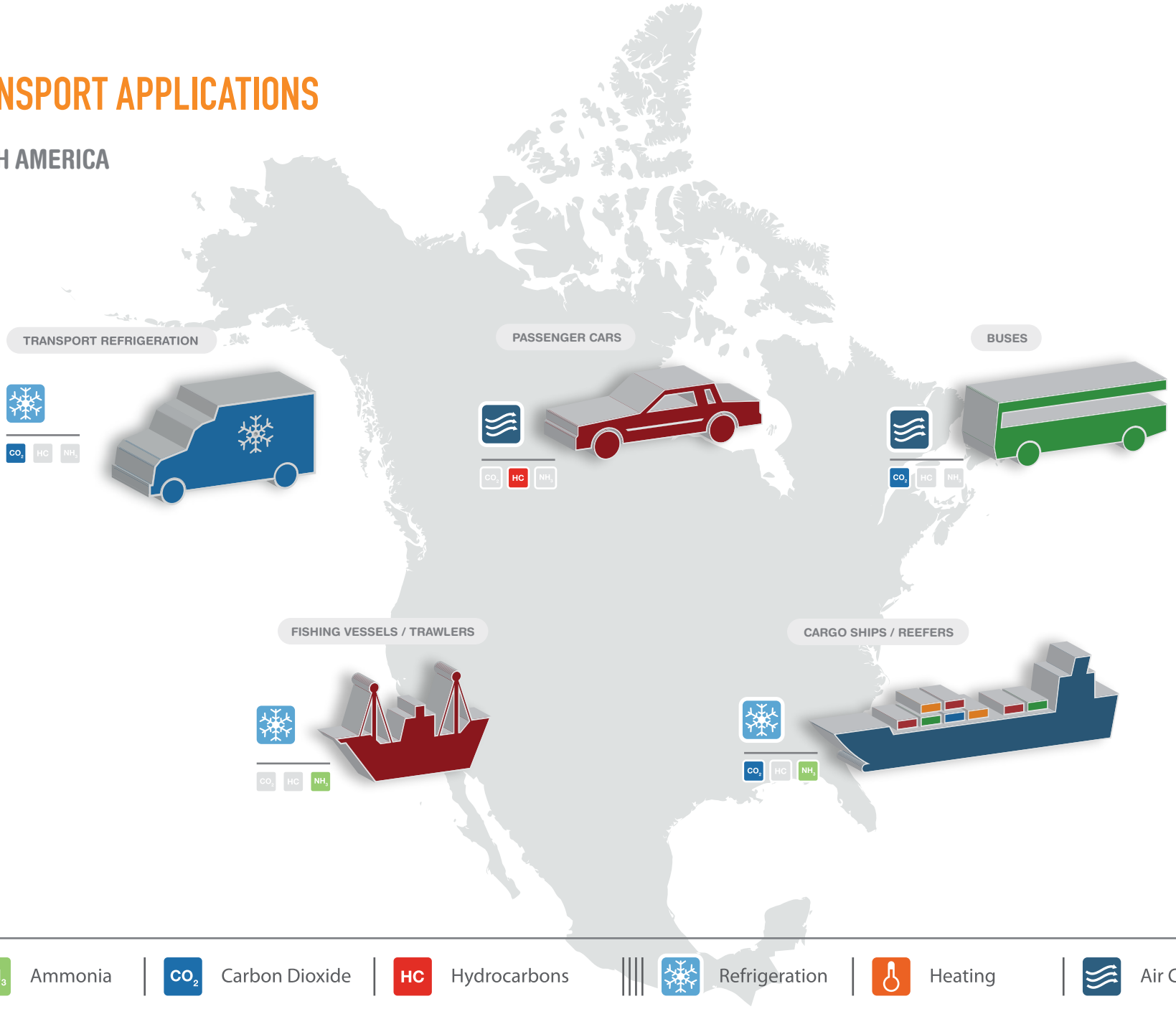
Bitzer

THE HEART OF FRESHNESS

TRANSPORT APPLICATIONS

NORTH AMERICA



NH_3 Ammonia | CO_2 Carbon Dioxide | HC Hydrocarbons | Refrigeration | Heating | Air Conditioning

TRANSPORT APPLICATIONS

HC: Hydrocarbons can work as a primary MAC system refrigerant or in secondary loop systems to ensure safer use. In North America, hydrocarbon refrigerants have been used as drop-in refrigerants to replace CFC-12 in an estimated 5 million car air conditioners. Although there are currently no restrictions on the use of flammable hydrocarbon blends in vehicle air-conditioning systems in Canada, hydrocarbons have not been approved as an acceptable substitute by the US EPA 's SNAP Program.

CO_2: In North America, CO_2 is currently being tested for use in refrigerated trucks and trailers, as well as high-efficiency intermodal containers. Cryogenic systems using recaptured liquid CO_2 have been deemed acceptable substitutes for ozone depleting substances in transport refrigeration equipment under the US EPA 's SNAP Program. The cryogenic systems have few moving parts to maintain and replace, allowing for near silent operation while also granting quick recovery of thermostat set-point temperature after delivery stops. Such systems usually operate by releasing the liquid refrigerant, held in pressurized tanks, through a spray nozzle at the ceiling of the trailer. The liquid CO_2 flashes into gas as it hits the warmer air in the trailer, absorbing the heat. Alternatively, the liquid CO_2 is circulated through a coil or plate heat exchanger and the vaporized gas vented outside. A third type of system stores CO_2 snow in a full-length ceiling bunker and cools as the snow melts.

Although the US EPA has not yet approved CO_2 as a substitute for HCFCs in intermodal containers, the world's first intermodal refrigeration system designed to use CO_2 has been undergoing a rigorous sea trial throughout 2012. Operating over temperature set points ranging from -7.6 to 55.4°F (–22 to 13°C) on Atlantic and Pacific routes, lasting up to 29 days, the CO_2 transcritical units are proving an environmentally sound alternative for the shipping of refrigerated goods. Using a patented, multistage compressor, variable speed drive, gas cooler, and flash tank, the unit's energy efficiency is equal to that of the industry's most energy efficient unit. These units also reduce greenhouse gas emissions by 28%, compared to previous models.

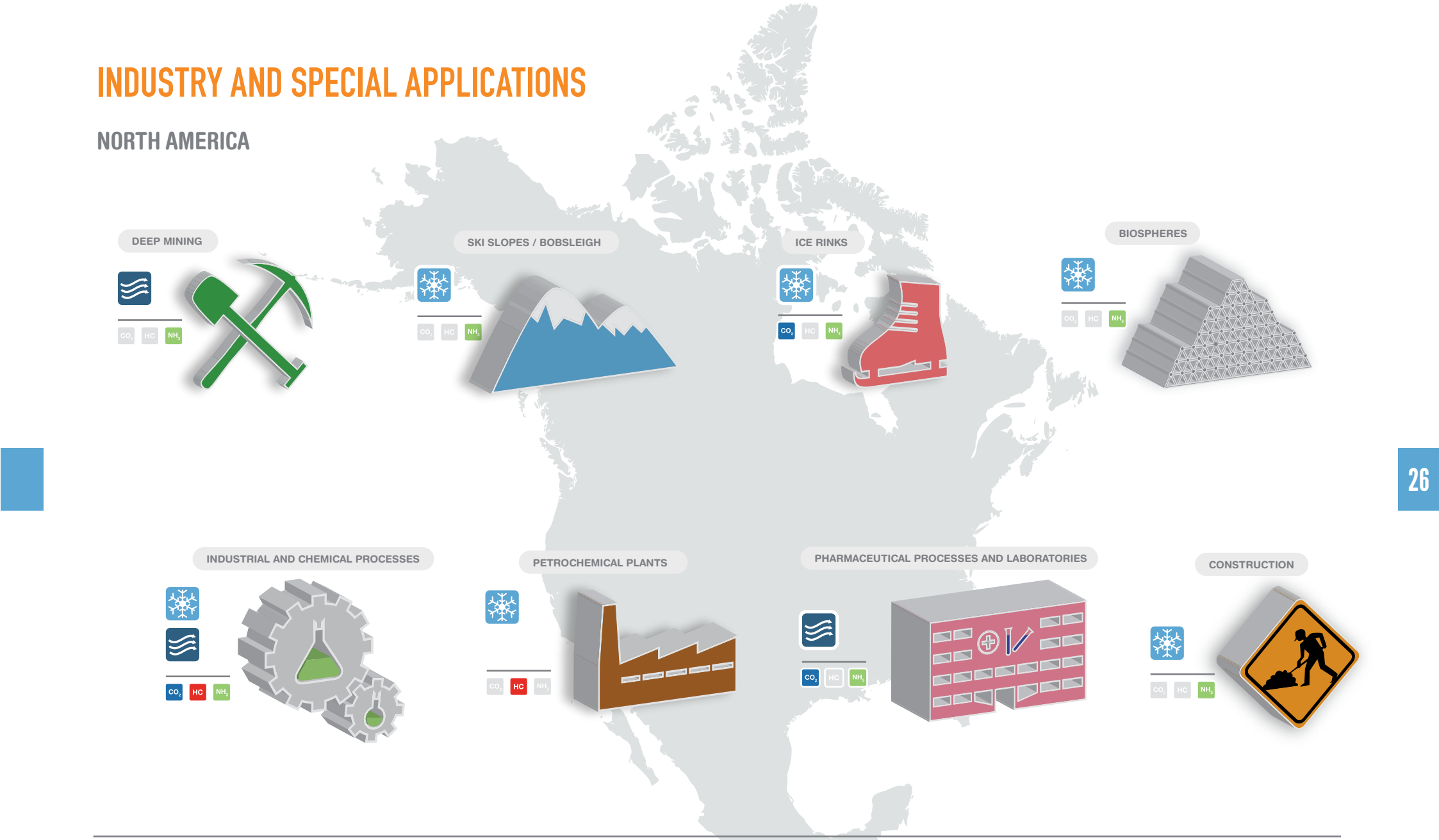
In the mobile air conditioning sector, all components for the CO_2 system have now been fully developed. As early as 2004, a CO_2 MAC demonstration vehicle was tested, in both city traffic and highway driving conditions, in Phoenix, Arizona's ambient temperatures of up to 109° F (43° C). Following this, in 2009, collaboration between a US and a German company resulted in North America's first all electric, CO_2 refrigerant system for hybrid and electric transit buses. The US EPA SNAP has approved the technology.

NH_3: Ammonia is used on large ships, as bases for trawlers to bring in their catch. For example, the "American Freedom," one of the world's largest reefer ships, is fitted with a cascade refrigeration system that uses four ammonia screw compressors to generate a total output of 4,500 kW in a system that is charged with 1,500 kg of ammonia. Fish pumped directly into the Freedom's hull are shock frozen in 36 vertical plate freezers and stored in cold stores in the hold.

CO_2: Recently, CO_2 transcritical systems, developed by a leading North American HVAC&R system supplier for container shipping, were put to extensive life-testing with a world-leading cargo company to prove their efficiency and reliability at all ambient temperatures around the world. The emission savings potential could be substantial, given that 65% of all refrigerated transport is done via container shipping.

INDUSTRY AND SPECIAL APPLICATIONS

NORTH AMERICA



NH_3 Ammonia | CO_2 Carbon Dioxide | HC Hydrocarbons | Refrigeration | Heating | Air Conditioning

INDUSTRY AND SPECIAL APPLICATIONS

INDUSTRIAL PROCESSES & LABORATORIES

In the chemical, petrochemical, and pharmaceutical industries, it is often necessary to run processes at a precisely specified temperature to prevent products from exceeding a certain temperature level. Large-sized refrigeration plants are often used to meet these strict cooling demands. The processes requiring refrigeration include:

- Separation of one gas from another by liquefying more of one gas. For example, the hydrocarbon refrigerant propylene (R1270) is used in the HCl liquefaction process
- Condensation of gases
- Solidification of one substance in a mixture to separate it from others
- Maintenance of a stored liquid at a low temperature to control pressure in the containing vessel
- Removal of reaction heat
- Humidity control for hygroscopic chemicals

HC: The petrochemical industry frequently uses propane, ethane, and ethylene as refrigerants, often in high capacity centrifugal chillers. Liquified Natural Gas (LNG) involves the purification, chilling, and liquefaction of natural gas by various processes, including refrigeration using hydrocarbon refrigerants. The production of p-Xylene by crystallization typically uses cascaded ethylene and propane or propylene refrigeration loops. In the pharmaceutical industry, cooling is often a prerequisite for assuring the effectiveness of medication.

NH_3: Examples of ammonia application include the McCormick Place Exposition Center in Chicago, Illinois, where ammonia refrigerant is used for turbine inlet air cooling. Here, the 3.3 MW system uses indirect heat exchange with liquid ammonia from ammonia chillers to cool inlet air to 50°F (-45.5°C).

The Roche manufacturing facility in South Carolina installed an ammonia refrigeration system to cool their state-of-the-art laboratories and production facilities. Global healthcare company Abbott uses ammonia refrigeration to cool its Nutritional Products Division in Arizona, where milk-based infant formulas and adult medical nutritional products are manufactured. The substantial refrigeration needed for pharmaceutical production at Bayer's Berkeley site is provided by ammonia.

CO_2: In North America, CO_2 has become a viable option for laboratory coolers and freezers. A laboratory refrigeration plant in Québec uses CO_2 for testing natural refrigerants. CO_2 is also used as a cooling medium in the Environmental Testing of electronic devices.

CONSTRUCTION

NH_3: Two important uses of refrigeration for big construction projects are the cooling of large masses of concrete and the freezing of soil to facilitate excavation. To ensure concrete hardens uniformly, large structures require massive refrigeration systems to remove the chemical heat generated by the curing concrete. These systems often use ammonia as the refrigerant, cooling water and making ice that provides the cement with the controlled environment needed to develop maximum strength.

Another application of ammonia refrigeration in the construction industry is the freezing of wet soil in the vicinity of excavations to prevent cave-ins during construction projects. Typically, pipes are driven into the soil surrounding the area where excavation is to take place. Then, cold brine circulates through the pipe coils and freezes the soil in its surrounding area. For example, the digging of three Interstate I-90 tunnels, completed in 2003 in Boston, involved the use of an ammonia plant to chill the brine and freeze the ground, enabling construction to proceed effectively and safely. The brine was cooled to an average temperature range of -13 to -22°F (-25 to -30°C).

One large dam structure had a 700 ton (2462 kW) per day flake ice system and a total of some 40,000 hp (29 840 kW) of refrigeration compressors for making the ice and chilling the water. Most refrigeration systems use liquid overfeed systems to distribute the ammonia refrigerant.

Completed in 1935, the Hoover Dam above the Colorado River was constructed by embedding nearly 120,000 yd (1000km) of 1 inch (25mm) steel pipe, which circulated ice water through the interconnecting concrete blocks. The onsite ammonia refrigeration plant that cooled the water was capable of creating a gigantic 450 kg ice block every day.

DEEP MINING

NH_3: As mine depths increase, so does temperature. Surface cooling and the use of ice slurries is a near continuous requirement to prevent excessive heat build-up and to ensure underground conditions are tolerable for miners. The use of ammonia is common in surface chillers serving deep mines, particularly to produce very cold water, and is gaining further interest for the production of ice slurries and/or hard ice for mine cooling. For example, to ensure adequate ventilation at Falconbridge – Kidd, an ammonia refrigeration plant is used.

In addition to its use in air conditioning, ammonia refrigeration packages are also employed in gold mine operations to condense and recover mercury vapor.

WINTER SPORTS

CO_2: 2011 saw the installation of the world's first 100% CO_2 ice rink in the Marcel Dutil Arena of the town of Les Coteaux, Québec. The company's "Eco-2-System" uses only CO_2, replacing the use of both HCFC-22 and ammonia, in a transcritical refrigeration cycle.

NH_3: In the Utah Olympic Park, ammonia is used to refrigerate the bobsled track over the winter months. The Olympic Sports Complex in Lake Placid, USA, whose track is nearly one mile long, is refrigerated using ammonia. The pipes running throughout the track are constantly pumped with ammonia, allowing them to regulate the temperature of the concrete upon which the track's ice rests. The ammonia is stored in a refrigeration plant, located on the premises. The temperature of the ammonia can be raised and lowered, depending on the weather, to ensure that the approximately inch and a half thick ice sheet remains smooth.

The Vancouver Winter Olympic and Paralympic Games also featured an ammonia cooled bobsled track, in which the heat waste from the refrigeration plant was captured and reused.

Many ice rinks in the US and Canada rely on ammonia refrigeration. In Montreal, ammonia-based systems are being used to replace existing HCFC systems. In the US, ammonia was used to create a temporary ice rink for the National Hockey League in January 2009, at the National Wrigley Field Stadium in Chicago.

SPECIAL APPLICATIONS: BIOSPHERE

NH_3/ H_2O: Biosphere 2, constructed in 1991, is a unique 3.13 acre (1.27 ha) environmental research facility in Oracle, Arizona. Designed to explore the complex interactions within life systems, the almost airtight structure houses different ecological systems. Two mechanical ammonia chillers and one lithium bromide chiller provide cooling to help maintain varying temperatures in six biomes.

Cooling in action

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Dual discharge air heat exchanger
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NATURAL REFRIGERANT ECOSYSTEMS: GLOBAL PERSPECTIVES

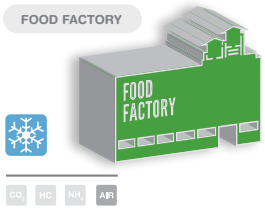
Driven by the need to tackle global warming, to save energy, and to conform to increasingly stringent environmental legislation, the market for the four natural refrigerants - ammonia, carbon dioxide, the group of hydrocarbons, and water - is experiencing significant growth all over the world. With growing interest in HFC-free refrigerants, this chapter summarizes key end-use applications using HFC-free refrigerants that have been successfully adopted in various world regions. These applications could present viable alternatives in Canada, Mexico, and the US, where their potential is sometimes not yet fully exploited. The chapter also looks at global market trends for several natural refrigerant applications.

GLOBAL PERSPECTIVES

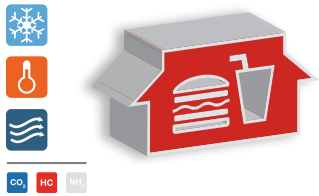
NATURAL REFRIGERANT APPLICATIONS FROM AROUND THE WORLD - POTENTIAL BUSINESS OPPORTUNITIES FOR THE NORTH AMERICAN MARKET

THE FOOD CHAIN

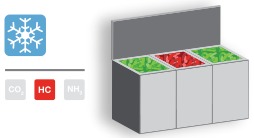
FOOD FACTORY



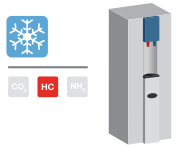
FAST-FOOD RESTAURANTS



SALAD REFRIGERATORS

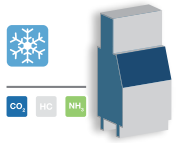


WATER FOUNTAINS

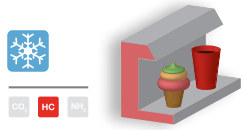


COLD DRINK DISPENSERS & ICE CUBE MACHINES

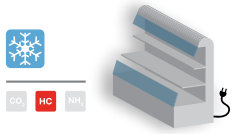
ICE FLAKE MACHINES



SODA MACHINES, MILKSHAKE & ICE-CREAM MACHINES

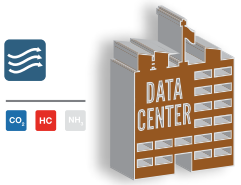


PLUG-IN DISPLAY CABINETS

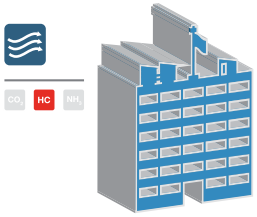


CITY AND BUILDINGS

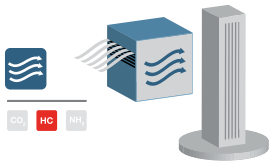
DATA CENTERS (SERVER COOLING)



PUBLIC & COMMERCIAL BUILDINGS



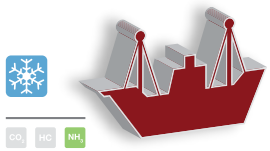
PORTABLE / MOUNTED AIR CONDITIONERS



HOT WATER HEATING AND SPACE HEATING

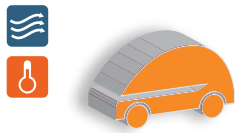
TRANSPORT

FISHING VESSELS / TRAWLERS

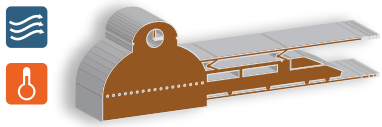


PASSENGER CARS

ELECTRIC VEHICLES

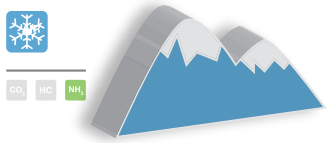


TRAINS



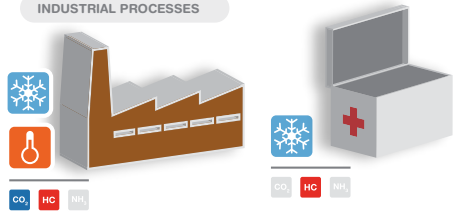
INDUSTRY AND SPECIAL APPLICATIONS

INDOOR SKI SLOPES



VACCINE COOLERS

INDUSTRIAL PROCESSES



NH_3 Ammonia | CO_2 Carbon Dioxide | HC Hydrocarbons | Refrigeration | Heating | Air Conditioning

GLOBAL PERSPECTIVES

THE FOOD CHAIN

FOOD PRODUCTION, PROCESSING, STORAGE AND DISTRIBUTION

NH_3: Ammonia systems are largely used in North America, Northern Europe, and Central and Western Europe. It is estimated that over 90% of the industrial refrigeration and cold storage industry - together with CO_2 and hydrocarbon refrigerants - use ammonia refrigeration plants in developed countries, whereas the market share in developing countries is 40%. In emerging economies such as Asia and South America, the use of ammonia is growing fast due to the rising demand for storage of frozen foods, fruit, and vegetables. Ammonia is also widely used in the Chinese, Indian, Thai, Indonesian, Pilipino, and Mexican fishery industries.

NH_3/CO_2: Ammonia/carbon dioxide cascade refrigeration systems are most widely used in Europe but are also gaining popularity across the world. In 2012, a 200,000 ton seafood cold storage logistics center with a CO_2/NH_3 cascade refrigeration system was built in Dalian, China.

CO_2: R744-only refrigeration systems are used to a lesser extent in the food storage and processing industries. For example, transcritical CO_2 cooling and freezing systems are used in the plant of Norwegian ice cream manufacturer Diplom-Is. Overall, market share of CO_2 for industrial refrigeration is estimated to be 10% in developed and 0% in developing countries; for heat pumps it is 5% and 0%, respectively.

HC: Propane has been available for use in industrial refrigeration and cooling applications, especially in large chillers, for over 10 years. Outside North America, installations of packaged air-cooled chillers adopting the hydrocarbon refrigerant R1270 are used by fruit growers in Ireland and the UK. However, market share in industrial refrigeration remains low, estimated to be about 0-2% worldwide. For industrial air-conditioning it is approximately 10% for developed countries and 5% for developing countries.

SUPERMARKETS

CO_2: Across the world the commercial refrigeration sector has experienced significant growth in the adoption of CO_2 systems in the food retail sector. European retailers are widely seen as the pioneers of this technology, with more than 1,300 supermarkets confirmed as using CO_2-only transcritical systems in 2011.

CO_2 transcritical refrigeration systems for supermarkets are also making inroads in Asia and Latin America. For example Japan installed over 100 CO_2 stores and one of the largest Japanese food retailers AEON is committed to converting all 3,500 existing stores to natural refrigerants. Tesco has installed three CO_2 transcritical stores in China and one in Thailand. CO_2 cascade systems are also being increasingly developed in emerging and developing economies. In Brazil, there are 31 CO_2 cascade system installations across the country. Brazilian retailer Verdemar is adopting CO_2 cascade refrigeration systems as a standard in new stores.

Also commercially available in Europe, for supermarkets and fishmongers, are CO_2 ice flake machines for filling display counters.

AIR: At the end of November 2009, 6 units of Pascal Air, a refrigeration plant that circulates air as a refrigerant, were delivered to a refrigerated warehouse of Fukazawa Reizo in Yaizu, Shizuoka Prefecture, Japan, for the purpose of freezing bonito and tuna. The system is composed of a turbo-type expander, a compressor, a primary cooler and a heat recovery heat exchanger. The system directly circulates ultra-low temperature air of -58°F to -148°F (–50 to –100ºC) in a refrigerated warehouse as refrigerant.

HC: In the UK and Germany retailers like Waitrose and Lidl are also investing in propane refrigeration technology for supermarket refrigeration systems. Several CO_2/propane hybrid systems were installed by UK retailer Marks and Spencer as well. Meanwhile, in Thailand, Tesco opened its first zero carbon store, featuring hydrocarbon powered fridges.

CO_2/NH_3: Ammonia/carbon dioxide solutions are estimated to have up to 5% market share in developed countries. South African Pick and Pay supermarket invested in this technology, replacing the conventional centralized refrigeration system with an R744/R717 cascade system, a system more suitable for a hot climate than R744 alone, which has lower thermal efficiencies at high ambient temperatures.

LIGHT COMMERCIAL REFRIGERATION

CO_2/HC: Many international consumer brands have started using natural refrigerants in their food and drink service equipment to reduce greenhouse gas emissions and energy consumption. Globally, by the end of 2012, The Coca-Cola Company will have deployed 800,000 HFC-free units of cold drink equipment using CO_2 and hydrocarbons; Red Bull 313,000 hydrocarbon beverage coolers; and Unilever 1.2 million units of hydrocarbon-based light-commercial equipment in every country of operation.

In the light commercial sector, Italian and British display cabinet manufacturers have developed CO_2 cabinets and wine walls.

FAST FOOD RESTAURANTS & COMMERCIAL KITCHENS: DRINK DISPENSERS, ICE MAKERS, & MEAT FREEZERS

HC/CO_2: In Europe, McDonalds is driving the use of natural refrigerants in point-of-sale appliances. In 2003, the franchising group opened the first "HFC-free restaurant" in Vejle, Denmark. Since then, McDonald's has developed natural refrigerant alternatives for eight pieces of refrigeration equipment, including: juice dispensers, ice cube machines, salad coolers, and meat/wall freezers. While hydrocarbon refrigerants were applied to smaller refrigeration applications, CO_2 was used in space heating and cooling, as well as in the refrigeration rooms. As of mid 2012, the company had already implemented 1,495 HFC-free meat freezers, 845 frozen fry dispensers, and 1025 reach-ins and salad displays. In addition, one Japanese and one French restaurant have each installed a CO_2 heat pump.

In the UK and Ireland, Subway has introduced energy efficient equipment across a number of stores, including equipment using hydrocarbons as the working fluid, which saves up to 13% more energy than existing products.

Also available in Europe for the hospitality industry are water coolers, ice flake machines, and under counter bar bottle coolers, refrigerated with hydrocarbons.

CITY & BUILDINGS

RESIDENTIAL HOUSING: REFRIGERATORS, HOT WATER & AIR-CONDITIONING

HC: Globally, more than 650 million hydrocarbon refrigerators have been sold, by major manufacturers such as Whirlpool, Haier and Sanyo. Since 1993 when the first Greenfreeze refrigerator debuted in Germany, hydrocarbon refrigerators have been sold in Europe, Japan, China, India, Indonesia, Mexico, South America, Cuba and parts of Africa.

Each year around 100 million household refrigerators and freezers are produced in the world, with hydrocarbon refrigerators and freezers representing between 35% and 40% of the total market share. In some countries, R600a (isobutane) and R290 (propane) are widely used in home appliances. Fire-safety measures for technicians are well established.

Australian, Chinese, European, and Indian companies are also producing a variety of hydrocarbon-based split and portable air-conditioners. Overall, HC low charge packaged solutions (less than 1 kg) are expected to see an increase in use, rising from a market share of below 1% today.

CO_2: In the water and space-heating sector in Japan, CO_2 heat pump technology has a high market penetration and has witnessed strong development in Europe and some countries in Asia. In Japan, where the technology was introduced with the name "Eco Cute" in 2001, the market share of CO_2 heat pumps in the residential hot water heater segment is as high as 98%. In China, the potential production capacity of CO_2 heat pumps has reached 100,000 units.

In addition, Norway and Austria, under the IEA Heat Pump Program's collaborative project on "Economical Heating and Cooling Systems for Low Energy Houses", witnessed the development and testing of brine-to-water CO_2 heat pump prototypes for domestic hot water-only operation and for combined space heating and hot water production. Both projects delivered promising results with high COP values.

PUBLIC & COMMERCIAL BUILDINGS: AIRPORTS, HOSPITALS, UNIVERSITIES, GOVERNMENT AND HISTORIC BUILDINGS, HOTELS, AND SHOPPING MALLS

CO_2: Hot water heat pumps using CO_2 are widely used in public buildings in Japan, where for example a commercial size Eco Cute, installed in ASA hospital in Hiroshima, provides 60% of the hot water demand. In South-West Japan a business hotel in Tottori uses a commercial CO_2 heat pump water heater. In Ireland and the UK the Cúil Dídin Nursing Care Facility and Beechdale Manor Care Home both use CO_2 heat pumps to satisfy all their hot water needs. O'Donovan's Hotel in Ireland also invested in a CO_2 heat pump water heater after seeking an efficient and renewable alternative to its hybrid solar-oil fired boiler system.

NH_3: Large ammonia chillers, which increase high efficiencies and reduce energy consumption, are now safely used in heating and cooling applications in densely populated areas across the world. For example, the Roche UK headquarters installed two ammonia chillers and three hydrocarbon chillers to provide office air conditioning and to cool the computer server room cooling. Terminal 5 at London Heathrow Airport uses a central ammonia chilling plant to provide comfort heating and cooling for passengers and workers. The energy center at the London Olympic Park features ammonia chillers as part of the low carbon heating and cooling system. On the other side of the world, New Zealand's Christchurch airport employs ammonia chillers to cool a freight hub, allowing temporary storage of shipments. Ammonia chillers are also used in London Homerton Hospital in Hackney, the world-famous UK children's hospital Great Ormond St, and the University Hospital in Akerhus, Norway, where chillers cater to the cooling needs of the operating theater and maternity and intensive care units. Middlesex University uses an ammonia slurry ice thermal storage system to provide

cooling for the whole university. To ensure safety, such systems include a minimal refrigerant volume through plate heat exchangers, separate sealed compartments, leak detection systems, ammonia scrubbers, and electrical switching outside the compartments. With regards to tropical countries, in Mauritius, two government buildings had their CFC-12 and CFC-11 chillers replaced with open screw ammonia chillers, helping save 1560 tons of CO_2 per year.

HC: In the last decade hydrocarbon (HC) chillers have started to gain acceptance as providers of comfort air conditioning and heating for buildings around the world. According to one estimation, the global market potential for HC chillers is $4 billion. In Europe, for example, R290 (propane) chillers have been installed in the historic Church House Westminster Abbey in London, UK, while Arhus University Hospital Skejby, Denmark has installed R600a (isobutane) heat pumps and R290 (propane) chillers. In Asia, several conversions to hydrocarbon chiller systems have taken place, including the Gaisano Country Mall, the Legenda Hotel and the Mandarin Restaurant in the Philippines. The Jusco Melaka shopping center in Malaysia also converted its cooling system to hydrocarbons, installing 50 25-50kW water-cooled packages and 100 split systems. A plan for industrial scale production of HC chillers has been put into action by one large supplier, which will be followed shortly by R290 heat pumps. This should further reduce the costs of these technologies and increase their uptake.

In addition to their use in chillers hydrocarbons can be used in ground source heat pumps (GSHP). This is the case in Buntingsdale Infant School in the UK, where heat is extracted from the ground and upgraded to a useful temperature by a R290 heat pump unit.

H_2O: The development of smaller air-cooled absorption chillers (10 RT to 150 RT sizes) promises residential and small commercial co-generation systems at high-energy efficiency levels. While such trends can already be seen among European manufacturers, it is expected that North America will also be an attractive market for small-scale sorption technology products in near future.

DATA CENTER COOLING

CO_2/HC: Data centers that house computer systems and components such as telecommunications and storage systems need to have rigorous temperature and humidity control to maintain the environment of the server components within the manufacturer's specified range. Recently, CO_2, which poses no danger to electrical equipment and is more efficient than air or water, was implemented as the refrigerant for data center air conditioning systems in London. The computer blade servers cool both the ABN Amro Data Center and Imperial College University's e-science computer suite.

In Denmark, the office building of EnergiMidt supplemented the traditional glycol-based free cooling system with a pumped CO_2 system for server cooling. The installation encompasses a cascade CO_2 system with propane compressors.

TRANSPORT APPLICATIONS

CARS & ELECTRIC VEHICLES

CO_2: The development of CO_2 MAC as an energy-efficient way to combine air-conditioning with heating capabilities is especially advanced in Europe, Japan, and the USA. Prototypes have been tested extensively, although, across the world, the commercialization of CO_2 MAC in passenger cars has been delayed. However, progress in Europe (status: January 2013) could revitalize developments in CO_2 MAC. Since one European automaker has announced that on safety grounds it will not use suggested low-GWP HFCs in its models, new activities in national and international fora have started to re-investigate the technical and commercial viability of CO_2. At the time of publication, no final conclusion about the renewed application of R744 in the future had been made.

New impetus for the use of CO_2 in mobile air-conditioning (MAC) systems could also come from the rapid evolution of hybrid electric vehicles and electric vehicles with electrically driven compressors. Here, CO_2 MAC optimizes the combined cooling and heating of vehicles with no or limited motor waste heat. Successful prototypes were already presented in 2011.

HC: Over 20 million car mobile air-conditioning (MAC) units worldwide have safely used hydrocarbon refrigerants, many converted from the high global warming refrigerant HFC-134a. An Australian vehicle manufacturer was the world's first to use hydrocarbons in its range of on/off road vehicles. Today, it is estimated that the share of hydrocarbons exceeds 10% in the Australian motor vehicle air-conditioning service sector. In 2011, an Australian supplier of hydrocarbon refrigerants reported 12% average sales growth. Hydrocarbons can work as a primary MAC system refrigerant or they can be used in secondary loop systems to ensure safer use. It should be noted that hydrocarbons are particularly suited to hot climates and applications with limited space such as mobile air conditioning systems.

BUSES, TRUCKS & TRAINS

CO_2/HC: Outside North America CO_2 MAC has so far been commercialized in around 30 buses, of which two were hybrid electric buses and one had a reversible operation for combined heating. In total, these busses have covered more than 3.3 million kms in Germany and Luxembourg. CO_2 systems for trains, which operate like a modern air-heat pump, are currently being tested in Germany, this time by the national train operator Deutsche Bahn.

Ongoing trials in Europe suggest that there is potential to increase the use of hydrocarbons in transport refrigeration applications, with propane being tested for use in refrigerated trucks and home delivery vans in the United Kingdom and Germany.

FISHING VESSELS & CONTAINER SHIPS

CO_2/NH_3: Although there is currently no legislative pressure exerted on the shipping industry, the use of low-GWP refrigerants such as carbon dioxide and ammonia, is expected to grow from the current global market share of below 5%. Onboard, NH_3 and CO_2 refrigeration plants produce ice, refrigerate seawater, and refrigerate compartments, allowing the catch to be chilled at 32°F (0°C) or frozen at -0.4°F (-18°C) while at sea. CO_2 used in cascade systems with ammonia can achieve a temperature of -58°F (- 50°C), saving up to 25% energy consumption as compared to single stage HCFC-22 systems. In the subcritical state, CO_2 is extremely suitable for use on ships because it is not flammable and it does not form toxic substances when in contact with hot surfaces.

INDUSTRY AND SPECIAL APPLICATIONS

INDUSTRIAL PROCESSES & LABORATORIES

NH_3: For cooling industrial processes such as in the chemical/pharmaceutical sector, ammonia refrigeration systems are used to provide effective and stable cooling performance. For example, the pharmaceutical company Novo Nordisk's Chinese factory uses eight ammonia refrigeration compressors for cooling insulin. In Europe, Neste Oil in Finland replaced its R22 refrigeration system with an ammonia system and an energy station in Norway installed industrial ammonia heat pumps for cooling and heating. In Belgium, a 500kW ammonia heat pump was installed in Emerson's factory in Welkenraedt, where waste heat from the factory is reused.

CO_2: CO_2 transcritical heat pump dryers are being used for product drying where they ensure that quality and texture of substances as varied as pharmaceuticals, fruits or pet food can be preserved.

CO_2/NH_3: CO_2 cascade systems have been used for various industrial sectors in Europe, Australia, Japan, China, Brazil, Canada, and the US. In China, the leading polysilicon manufacturer, Jiangsu Zhongneng adopted a CO_2/NH_3 cascade cooling unit in its factory.

SOLAR REFRIGERATION: VACCINE COOLERS & FOOD REFRIGERATORS

HC: In Europe, several companies from Denmark, the UK, and Switzerland have developed hydrocarbon (R600a) solar powered vaccine coolers. A $2.7 million grant by the Global Environment Facility (GEF) will support the installation of 75 SolarChill vaccine coolers in community clinics and 25 SolarChill food refrigerators in schools, small enterprises, and hospitals in Kenya, Swaziland, and Colombia.

WINTER SPORTS

NH_3: In addition to cooling ice rinks, bobsled, luge, and skeleton refrigerated tracks, another winter sport application using ammonia, which is found outside North America, is indoor ski slopes. The SNORAS indoor skiing snow arena in Lithuania and the world's third largest indoor snow park in Dubai are both cooled using NH_3. The snow park in Dubai is the main attraction at the Mall of the Emirates Shopping Center in Dubai, which offers 5 ski slopes and is covered with 6000 tons of snow.

SPECIAL APPLICATIONS: SPACE STATION

NH_3: One of the most striking examples of the use of ammonia in special applications is for air-conditioning in the international space shuttle.

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NATURAL REFRIGERANTS IN NORTH AMERICA TODAY

EMERGING MARKETS

LIGHT COMMERCIAL REFRIGERATION IN AMERICA

With consumer goods brands investing more and more into global environmental stewardship, demand for products that use alternative refrigerants such as R744, R290, and R600a is growing rapidly in North America. Find out which companies are trail-blazing when it comes to natural refrigerants in America's light commercial refrigeration sector on...

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CO_2 SUPERMARKETS IN CANADA

With over 65 food retail stores using or having made a purchase order for CO_2 secondary, cascade, and transcritical refrigeration systems, Canada is taking the lead when it comes to implementing CO_2 refrigeration systems in North America. See a map showing the CO_2-only supermarkets by Pro vince, reported benefits of CO_2 systems, and the different strategies that have incentivized the uptake of HFC-free solutions on...

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CO_2 SUPERMARKETS IN THE US

Driven by the supermarket industry's goals to lower refrigerant charge and lower leak rates, CO_2 refrigeration systems are gaining ground in the United States. See a map showing the CO_2-only supermarkets by State and read about the US Environmental Protection Agency's (EPA) GreenChill Partnership, which is spurring investment in CO_2...

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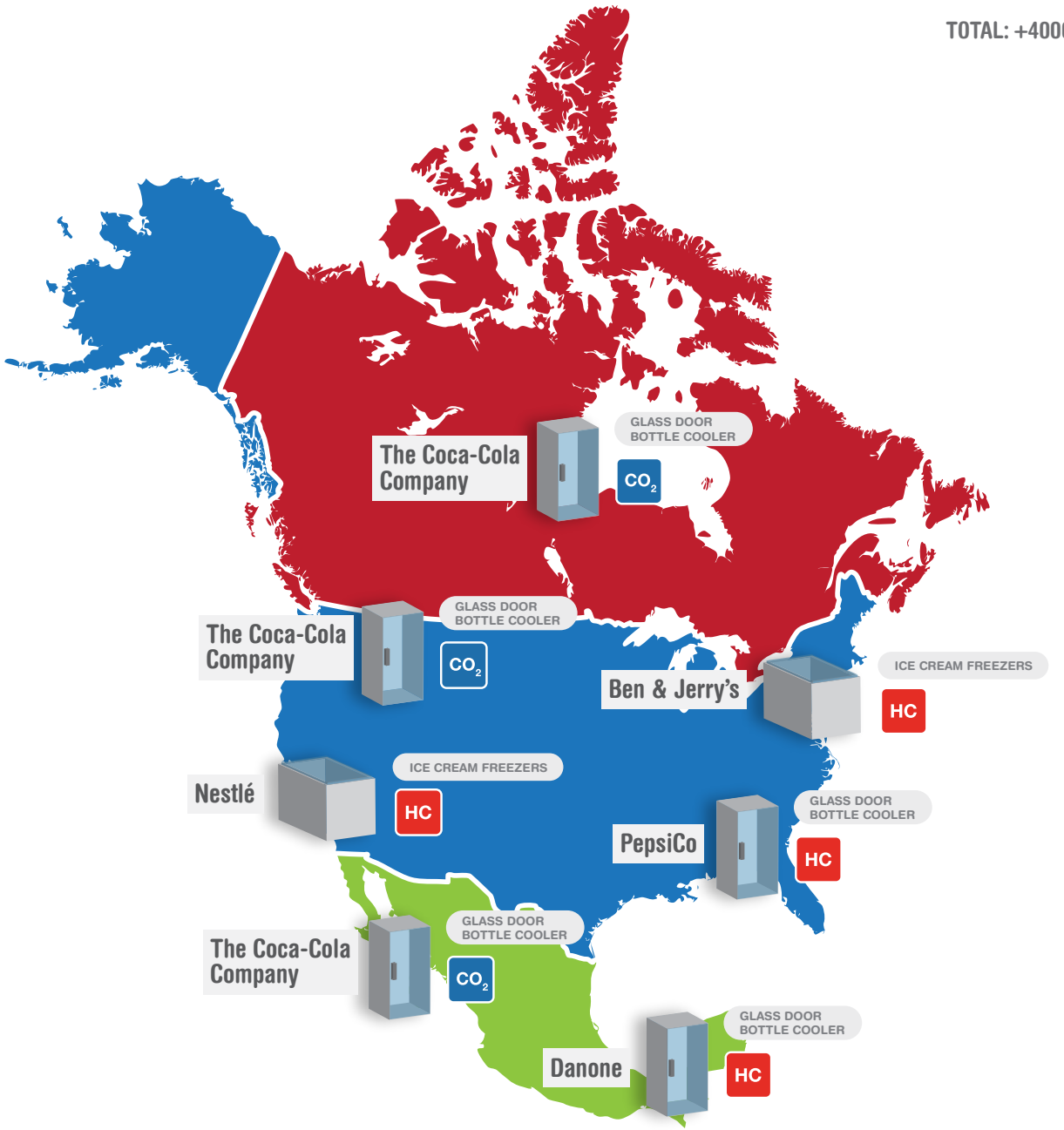
LIGHT COMMERCIAL REFRIGERATION IN NORTH AMERICA*



** Please note that this is a non-exhaustive list. If you do not see your company listed please feel free to contact us to add your data to the map. Send an email to research@shecco.com*

Natural refrigerants have proven themselves to be more efficient and energy-saving than HFC refrigerants. They are more and more commonly used in self-contained units and vending machines. Leading global consumer brands like Unilever, PepsiCo, Danone, and The Coca-Cola Company have started accelerating the transition to Hydrocarbons and CO_2 to reduce greenhouse gas emissions produced by their coolers and vending machines in North America.

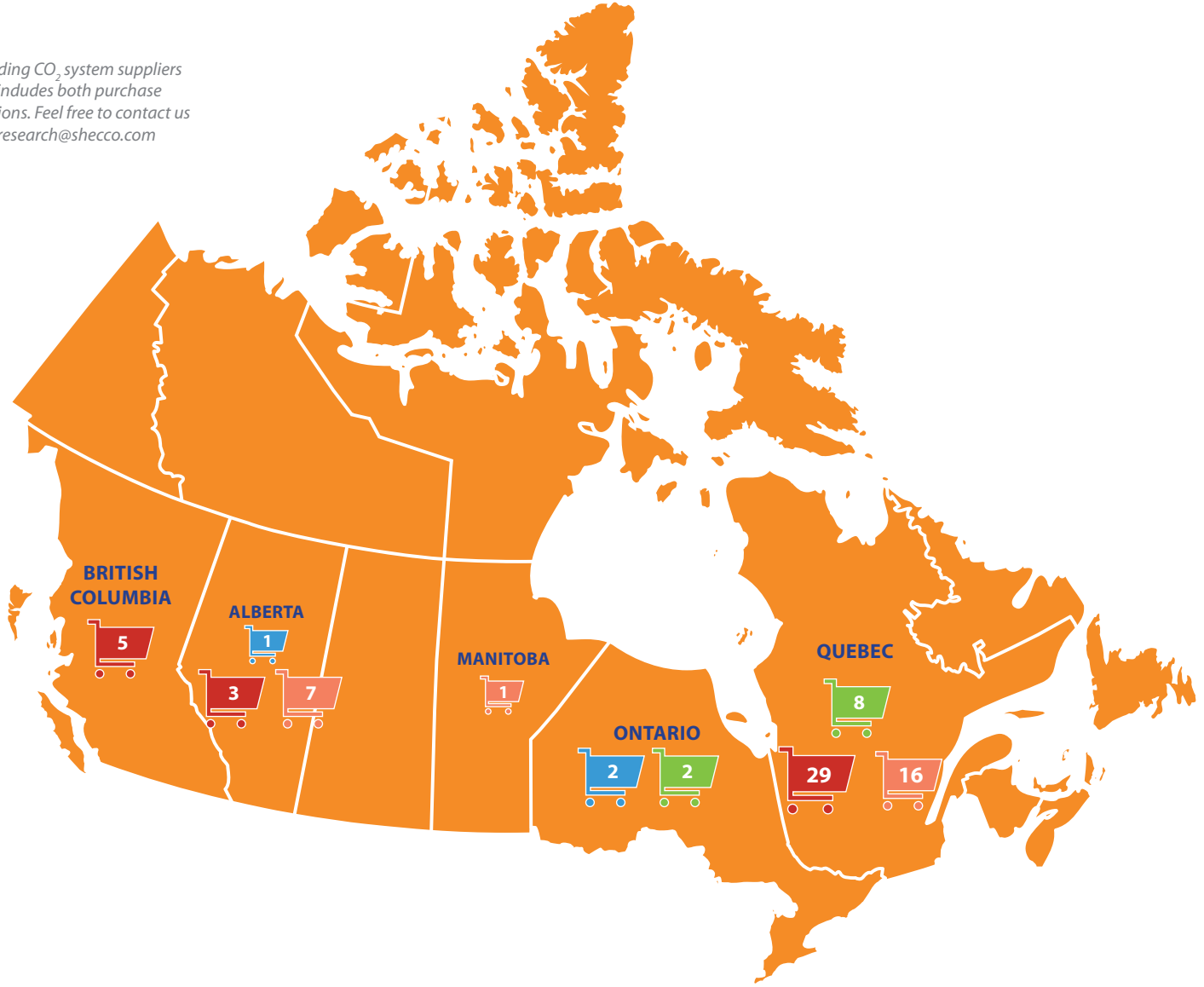
HC: Across North America, PepsiCo has already installed 35 units of hydrocarbon bottle coolers. In Canada, Ben & Jerry's stores received federal approval in 2008 to use hydrocarbon propane freezers. Ben & Jerry's also successfully petitioned the Environmental Protection Agency (EPA) in 2009, to use purified propane in ice cream freezers in 21 stores in Boston, Northern Virginia, Vermont, and Washington, DC. Following the US EPA SNAP approval for hydrocarbon refrigeration, Unilever and Ben & Jerry's jointly announced, in February 2012, that they planned to roll out 700 hydrocarbon refrigerant ice cream freezer cabinets in the United States within the year. Fresh and Easy has, since 2009, deployed self-contained coffin freezer cases (from AHT Cooling Systems, an Austrian company with US offices in Hanahan, S.C.) throughout the chain and, in 2011, began trialing propane cases. Danone has 1,000 coolers using hydrocarbon technology in a number of countries, including Mexico.

CO_2: In the United States, following the EPA's approval of CO_2 use in new vending machines in 2012, end-users can now move ahead with installing more CO_2 vending machines and dominant equipment manufacturers are more confident about supplying units to the US market. The Coca-Cola Company has committed to only purchasing machines which use CO_2 refrigerant. Until now, The Coca-Cola Company has introduced 3,232 units of CO_2 bottle coolers to the North American market (350 in Canada; 1382 in the US, and 1500 in Mexico. In 2009 PepsiCo had 30 vending machine units using CO_2 refrigerant in th US market and 28 CO_2 vending machines in Canada, originally placed around Winter Olympics areas in Vancouver, in 2010.

CO_2 SUPERMARKETS IN CANADA

DATA BY PROVINCE

These figures are based on a 2012 survey of leading CO_2 system suppliers and commercial end-users. The data collected indudes both purchase orders for CO_2 systems and completed installations. Feel free to contact us to add your data to the map. Send an email to research@shecco.com



2012

- SECONDARY INSTALLATIONS
- CASCADE INSTALLATIONS
- TRANSCRITICAL INSTALLATIONS

2013

- SECONDARY INSTALLATIONS
- CASCADE INSTALLATIONS
- TRANSCRITICAL INSTALLATIONS

CO_2 SUPERMARKETS IN CANADA

In Canada, several regional initiatives have helped to incentivize investment in CO_2 refrigeration by offering rebates and financing to offset the cost of new, energy efficient commercial refrigeration installations. These initiatives include the Refrigeration Optimization Programme (OPTER) administered by Québec's Ministry of Natural Resources and Wildlife, the Power Sense Programs in British Columbia, the Manitoba Commercial Refrigeration Program; and Efficiency Nova Scotia. Perhaps one of the most influential of these is OPTER, a program that encourages large refrigeration system owners to make the switch to the more environmentally friendly types of systems that are available today.

Some of the first supermarkets in Canada to use CO_2 refrigeration were the Wal-Mart Burlington supercenter and the IGA supermarket in St-Félix-de-Valois, which opened in 2009 as part of the Sobeys Québec inc. Corporation. The 129,000 sq. ft. (11,984m^2) Wal-Mart store incorporates a low-temperature CO_2 secondary coolant system with a medium temperature glycol secondary system.

Since then, Sobeys has taken the lead in implementing CO_2 refrigeration transcritical systems, with a total of 36 installations completed and 22 more approved for 2013. CO_2 is a core part of Sobeys' goal to reduce GHG emissions by 15% by the end of 2013. Its engineering department has partnered with Québec-based refrigeration system manufacturers to develop new technology that can be utilized in both low and medium temperature refrigeration applications. The technology is proving to have additional benefits, including better temperature control and lower maintenance costs. Heat-recovery systems also capture waste heat from the CO_2 refrigeration system for space and water heating, further reducing Sobeys' energy consumption, emissions, and operating costs.

Sobeys' investment in CO_2 follows a National Initiative, undertaken in 2010, which reviewed various CO_2 systems to determine the direction the retailer should take. The consensus from this initiative was that there were substantial benefits to eliminating chemical refrigerants completely and focusing on full transcritical CO_2 refrigeration systems.

Comparing other parameters of HFC and CO_2 transcritical systems, Sobeys reports the following:

- Installation cost: 10% lower than an HFC system, as a result of using less copper and only one pipe size
- Installation time: same as an HFC system
- Refrigerant cost: 94% reduction in cost compared to HFC
- GWP: 99% reduction compared to HFC
- Energy cost: 15% reduction compared to HFC
- Maintenance cost: 50% reduction compared to HFC
- Building heating cost: 75-85% reduction compared to HFC

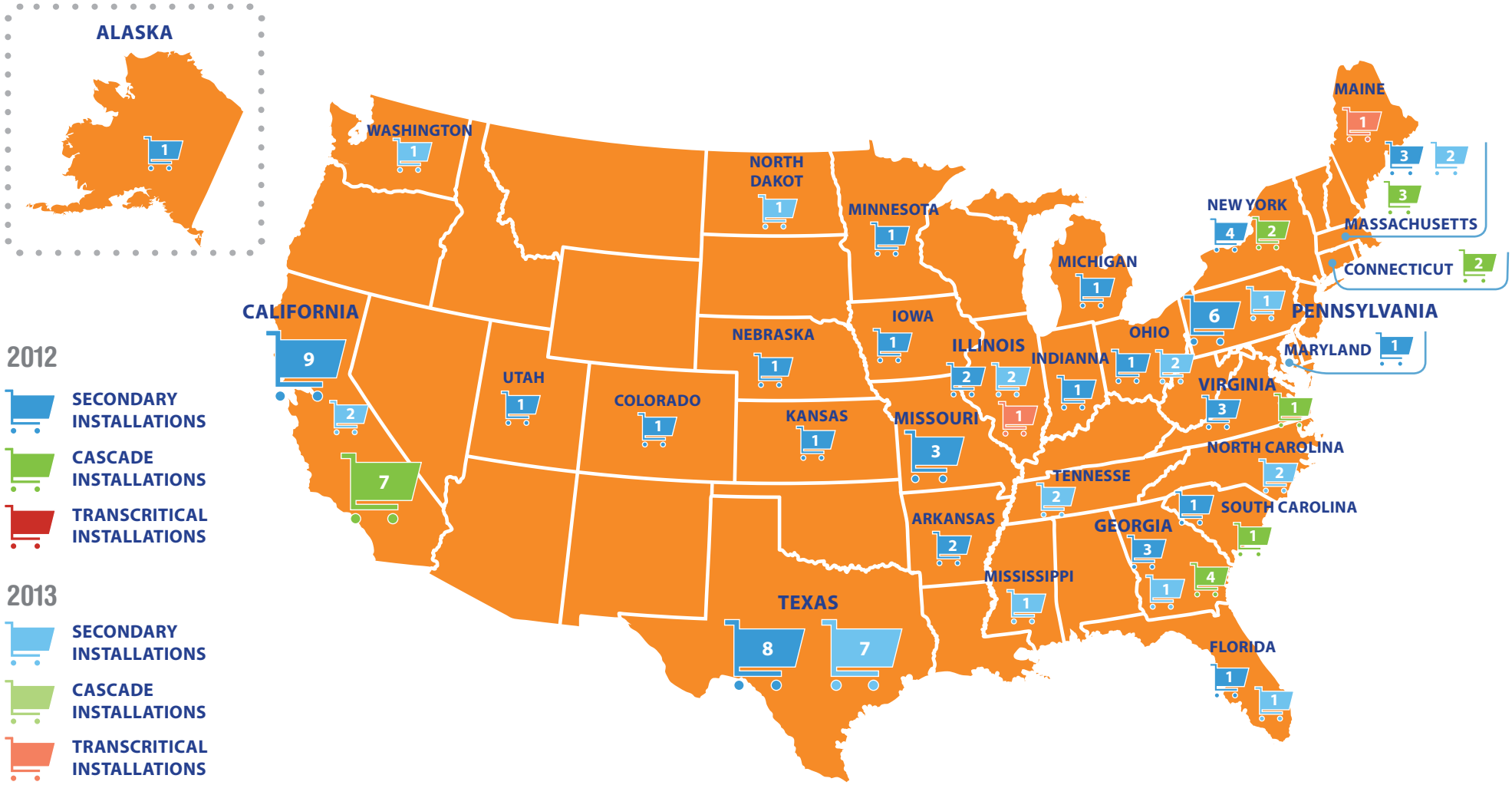
Overwaitea Food Group (OFG) is one of the latest Canadian retailers to have invested in CO_2 transcritical refrigeration. The Urban Fare Express store, which had already established aggressive goals for green operations in every area of its business, began experimenting with CO_2 refrigeration systems in 2010 and installed a CO_2 only system, joining the ever-growing list of HFC (hydrofluorocarbons)-free grocery stores in Canada.

The store uses a transcritical CO_2 booster system and construction of the 23,000 sq. ft. (2137 m^2) Urban Fare Express entailed retrofitting a former Olympic Village structure to accommodate a grocery store and all of its associated systems.

CO_2 SUPERMARKETS IN THE UNITED STATES OF AMERICA

DATA BY STATE

These figures are based on a 2012 survey of leading CO_2 system suppliers and commercial end-users. The data collected indudes both purchase orders for CO_2 systems and completed installations. Feel free to contact us to add your data to the map. Send an email to research@shecco.com



2012

- SECONDARY INSTALLATIONS
- CASCADE INSTALLATIONS
- TRANSCRITICAL INSTALLATIONS

2013

- SECONDARY INSTALLATIONS
- CASCADE INSTALLATIONS
- TRANSCRITICAL INSTALLATIONS

CO_2 SUPERMARKETS IN THE UNITED STATES OF AMERICA

CO_2 technology was reintroduced in the Unites States in 2001, when laboratory testing of low-temperature CO_2 secondary systems was initiated. After extensive investigation of the system's operation, display-case and unit-cooler performance, and various piping configurations and control methods, the first US system was installed in mid-2006, in the 136,000 sq. ft. (12,635m^2) Sam's Club (a division of Walmart) in Savannah, Georgia. By using this technology, the HFC charge was reduced by 34%.

Then, in early 2008, the first low-temperature CO_2 cascade system was installed in a Price Chopper store in Saratoga, N.Y. Here, the CO_2 is condensed by a medium-temperature refrigeration system using R-404A, which also chills propylene glycol for the relocated dairy and beverage departments.

Since then, many more retailers have opted for CO_2 refrigeration. For example, Delhaize America has three stores which operate with low temperature CO_2, or as a cascade, and one CO_2 transcritical project is planned in Maine for 2013. In 2009, Whole Foods completed their first CO_2 store project, a low temperature CO_2 secondary system. This was followed in 2010 by the company's installation of two CO_2 cascade systems in California and Massachusetts. The company is now working on the design of their first CO_2 transcritical store.

In the US the voluntary GreenChill Partnership, an initiative of the Environmental Protection Agency (EPA), is helping to spur the switch to natural refrigerants and CO_2 refrigeration. Aimed at reducing refrigerant emissions from supermarkets and decreasing the impact of supermarket refrigeration on the ozone layer and climate change, GreenChill represents more than 8000 supermarkets in all 50 states and Washington, DC. After starting with just 10 founding Partners, the GreenChill Partnership base has increased more than five-fold within four years.

The Star Market store at Chestnut Hill in Newton, Massachusetts was one of the first supermarkets to receive the platinum-level Store Certification Award for advanced refrigeration technology that prevents harmful refrigerant emissions, the highest certification level that can be obtained from the Environmental Protection Agency's GreenChill Partnership. It received the award thanks to the installation of a glycol and CO_2 secondary refrigeration system, which reduced refrigerant charge by 85%.

Other GreenChill platinum-level stores include the Fresh & Easy Neighborhood Market in Folsom California. The store received the award for the CO_2 refrigeration technology that uses medium-temperature glycol to condense low-temperature CO_2. Fresh & Easy first installed a subcritical CO_2 system over two years ago. It also utilizes self-contained propane cases.

SUPERVALU created the first US supermarket store with only natural refrigeration systems installed throughout. The store was named 'Best of the Best' at the GreenChill '2012 Environmental Achievement Awards'. The award was given to the Carpinteria store in California, which recently achieved Platinum-Level store certification as well. The store uses ammonia as the primary refrigerant in a system with 250 lbs (approximately 113 kg) of ammonia located in an outdoor enclosure. Here, CO_2 is condensed in a "combined" refrigeration system, in which one vessel contains liquid that is pumped to the low and medium temperature display cases and walk-in cabinets. The self-contained merchandisers use propane as the refrigerant.

In Hatfield, Pennsylvania, ShopRite, known in North America for its commitment to organic, local, and specialty foods, was awarded GreenChill Gold Certification, also for a CO_2 cascade system, installed with the aim of reinforcing its brand image, increasing its energy efficiency, and decreasing its environmental impact. The refrigeration systems use lower refrigerant charges, operate at lower pressures, and run more efficiently, utilizing 100% of the heat transfer surface.

Another GreenChill Gold store is the Wegmans' Woodmore store in Maryland, which also uses a CO_2 refrigeration system to cool the freezer cases, while glycol is used to cool the medium temperature dairy and meat cases R404A is used to chill the glycol. The success of this store led to the installation of a CO_2 refrigeration system in their Pottsville, Pennsylvania distribution center as well.

NATURAL REFRIGERANTS IN NORTH AMERICA TODAY

POLICIES & CASE STUDIES

NORTH AMERICAN POLICIES AND POLICY DRIVERS

Laws, standards, and rules are among the decisive factors for building a prosperous business around natural refrigerants within a framework of investment security and joint leadership. See a rating of North American legislation and initiatives and their impact on the adoption of HFC-free solutions, as well as outstanding national strategies serving as a role model, on...

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CASE STUDIES

Leading HVAC&R system and component suppliers present real-life examples of successfully working natural refrigerant technologies in North America. Read realistic accounts of how alternatives to HFC refrigerants have been used, the advantages they provided, the challenges that must be overcome, and the drivers behind each project, on...

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NORTH AMERICAN POLICIES AND POLICY DRIVERS

NORTH AMERICAN POSITION IN THE INTERNATIONAL CONTEXT

Although "lightly" regulated in North America compared to other parts of the world, f-gases and their associated regulatory landscape could soon change, as suggested by the North American position in the international arena.

The US, Canada and Mexico have, for three consecutive years, tabled amendment proposals to the Montreal Protocol on Substances that Deplete the Ozone Layer. If adopted, the desired changes could eventually lead to an international agreement to phase-down HFCs. At the same time, the three North American countries have signed up to a declaration[2] that calls on countries "to explore further and pursue under the Montreal Protocol the most effective means of achieving the transition to low global warming potential alternatives". The 'Bali Declaration' contributes to the growing international momentum to instigate and accelerate a transition to alternative gases.

In June 2012, at the Rio+20 United Nations Conference on Sustainable Development, UN countries, including North American countries, unanimously recognized "that the phase-out of ozone depleting substances (ODS) is resulting in a rapid increase in the use and release of high global warming potential hydrofluorocarbons (HFCs) into the environment." This was stated in the conference outcome document, where it was also noted that the countries "support a gradual phase-down in the consumption and production of HFCs"[3].

Taking into account that a new international agreement involving all Montreal Protocol Parties could prove sluggish, North American countries are also driving the Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants[4] (CCAC). US Secretary of State Hillary Clinton announced the initiative in February 2012, along with an initial commitment of $15 million, $12 million from the USA and $3 million from Canada, to get the coalition up and running. Since then, the membership of the Coalition has been growing. As of December 14, 2012, less than 12 months after its launch, CCAC country members grew from 6 to 25, underlining a worldwide interest in the voluntary initiative.

INTERNATIONAL CONTEXT DRIVING NATURALS IN NORTH AMERICA

The push by North American countries for change in the international arena potentially reflects the importance of the international context as a significant policy driver for the uptake of natural refrigerants in the region. This is suggested by survey results pertaining to policy drivers, taken from shecco's North American Natural Refrigerant Survey, which was launched in March 2012 to collect industry perspectives on the use of natural working fluids in the Canadian, Mexican and USA heating, air conditioning and refrigeration markets.

As of the end of 2012, a total of 348 individuals rated the impact of different policy drivers on natural refrigerants in the North American HVAC&R industry over the coming years.

More than two thirds of respondents (66.9%) thought that the global Hydrochlorofluorocarbon (HCFC) phase-out and the need to replace remaining HCFC installed base will be an influential policy driver for the North American HVAC&R industry over the coming years.

More than half of respondents (60.8%) believed that a potential future global agreement or national regulations to phase-down HFCs will have a high impact on the industry.

2 Bali Declaration on Transitioning to Low Global Warming Potential Alternatives to Ozone Depleting Substances http://ozone.unep.org/new_site/en/Treaties/decisions_text.php?dec_id=1114

3 The Future We Want – Rio+20 Outcome Document, paragraph 222, http://www.uncsd2012.org/content/documents/727The%20Future%20We%20Want%2019%20June%201230pm.pdf

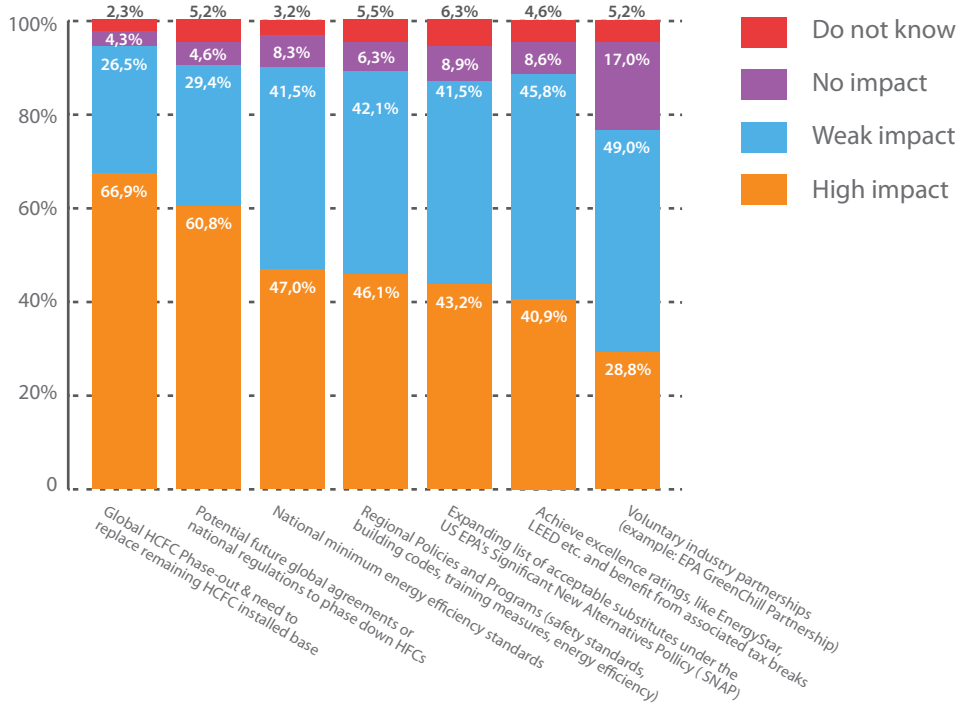
4 Climate and Clean Air Coalition to Reduce Short Lived Climate Pollutants. Available from: http://hqweb.unep.org/ccac/ (Accessed: December 2012)

Third place in the ranking of policy drivers that have a high impact was shared by 'national minimum energy efficiency standards' as well as 'regional policies and programs (safety standards, building codes, training measures, energy efficiency).' Nearly half of the respondents (about 47%) assessed both as having a high impact.

The ranking of the most significant policy drivers remains unchanged when both high and weak impacts are considered. The 'HCFC phase out' and a 'potential future agreement on an HFC phase out' remain at the top of the ranking, with regional policies and programs (safety standards, building codes, training measures, energy efficiency) and 'national minimum energy efficiency standards' coming third.

Surprisingly, expanding the list of acceptable substitutes under the US EPA 's Significant New Alternatives Policy (SNAP) was seen as having a high impact by just 43.2% of respondents. Still, the total share of respondents that believed SNAP to have an impact - be it strong or weak – was more than three quarters (85%).

Overall, the respondents ranked the international action on HCFCs and HFCs to have a high impact on the growth of natural refrigerant market in North American countries. This goes hand in hand with the highly active role that these countries play in the Montreal Protocol negotiations.



NORTH AMERICAN POLICIES: KEY INITIATIVES AFFECTING THE UPTAKE OF "NEW" TECHNOLOGIES

INTRODUCTION AND METHODOLOGY

The prospect of increasing costs regarding the availability of hydrofluorocarbons (HFCs) is expected to enhance the uptake of technologies relying on low GWP refrigerants such as hydrocarbons, ammonia, and CO_2. This provides a strong growth potential for those in the HVAC&R industry that embrace the opportunity. At the same time, the need to replace remaining stock of HCFC equipment provides further opportunities to leapfrog technologies that are already tagged as "polluting."

Zooming in on the United States and Canada, the ensuing section lists examples of some policy initiatives in North America that are thought to have a direct bearing on the refrigerant choice of the HVAC&R industry of tomorrow.

The impact of the initiatives is assessed using four criteria. The individual legislation is rated based on its impact on the uptake of natural refrigerants. The rating for each criteria ranges from 0 (no impact) to 4 (high impact), and gives an assessment of the magnitude of the impact. The selected criteria represent four key areas in which policy initiatives can enable the widespread use of CO_2, NH_3, and HCs, namely:

- **Training & Know-How:** This criterion analyses how the legislation affects the creation of the skills necessary for handling natural refrigerants. This includes certification for the manufacture, supply, commissioning, installation, maintenance / monitoring, and decommissioning of HFC-free systems.
- **Technology & Safety:** This criterion looks at how the policy document affects the availability, durability, reliability, safety, efficiency, and cost-effectiveness of production processes, materials, refrigerants, servicing and disposal infrastructures, as well as components and systems.
- **Awareness & Psychology:** This criterion investigates if and how information and awareness-raising campaigns, business-to-consumer and government-to-consumer, address misconceptions about natural refrigerants within the industry and the wider public.
- **Economy & Costs:** Direct support for non-fluorinated gases is one of the most important measures needed to accelerate the deployment of natural refrigerant solutions. This criterion looks at the effectiveness of incentive-based measures (taxes, subsidies, marketable trading permits, funding/ grants) and command-and-control measures (standards) in reducing price gaps.

NORTH AMERICAN POLICIES: SIGNIFICANT NEW ALTERNATIVES POLICY (SNAP) PROGRAM (US EPA)

ACCELERATING ACCEPTANCE OF NATURAL REFRIGERANTS IN MORE HVAC&R APPLICATIONS

The Significant New Alternatives Policy (SNAP) Program[5] is the US Environmental Protection Agency's (EPA) program for evaluating and regulating substitutes for the ozone-depleting chemicals that are being phased-out under the stratospheric ozone protection provisions of the Clean Air Act (CAA). SNAP evaluates the risk of alternative compounds compared to those of ozone-depleting compounds and the available alternatives. The EPA is authorized to identify, assess, and publish lists of acceptable and unacceptable substitutes for class I or class II ozone-depleting substances for different HVAC&R applications.

Therefore, 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. With the international context driving R&D in new refrigerants, the SNAP program has been very active over the last couple of years in approving new substances. In the area of natural refrigerants, the approval of hydrocarbons in domestic and stand-alone retail refrigerators at the end of 2011 was notable, as it opened the US market to flammable refrigerants. Approval of additional small charge equipment could follow suit. A number of substitutes have been recently reviewed under the SNAP program and more submissions are expected. The EPA is looking at a number of refrigerants across the board, including both fluorinated and natural substances, such as hydrocarbons and CO_2.

In August 2012, the use of CO_2 in new vending machines was approved. Activities concerning other end-use applications, including residential AC and retail food refrigeration, are moving fairly quickly.

Besides approving substitutes, the program also allows the withdrawal of substances from the list. For example, a few months after SNAP approved the use of hydrocarbon refrigerants in domestic and plug-in commercial refrigeration equipment, formal petitions were filed in the US, asking the Environmental Protection Agency to withdraw federal approval for the use of one of the most commonly used fluorocarbon refrigerants, R134a, in new domestic and retail stand-alone refrigeration. A similar petition, filed earlier on, asked the EPA to remove R134a from the list of approved substitutes in Motor Vehicle Air Conditioning. The petition has now been found complete by the Agency, which will initiate a notice and comment rulemaking in response to it[6].

As the SNAP program requires a case-by-case analysis of the different refrigerants in specific applications, several natural refrigerants must still be assessed and approved.

An example of this is equipment that is typically used in food retailing environments. Many types of equipment using the natural refrigerants CO_2, ammonia, or hydrocarbons (HCs) are pending assessment or approval (indicated with an "X" in the table on the next page). As of October, depending on system type and application, the natural refrigerants carbon dioxide (CO_2), ammonia, and hydrocarbons (HC) have been approved in new systems (N) and retrofit applications (R). However, some applications have yet to be approved (X), as indicated in the following table:

5 US EPA Significant New Alternatives Policy (SNAP) Program. Available from: http://www.epa.gov/ozone/snap/ (Accessed: December 2012)

6 NRDC/IGSD/EIA Petition to Remove HFC-134a from the List of Acceptable Substitutes in household refrigerators and freezers and stand-alone retail food refrigerators and freezers under the SNAP Program. Available from: http://docs.nrdc.org/globalwarming/files/glo_12042701a.pdf (Accessed: March 2013)

	REFRIGERANT		
Application/ type of equipment	**CO_2**	**Ammonia**	**HC**
Vending Machines	N	X	X (R441A approved but rule with use conditions pending)
Retail Food Refrigeration	N	N (ammonia vapor compression with secondary loop)	N (stand-alone)
Cold Storage Warehouses	N	N (absorption or compression)	X
Industrial Process Refrigeration	N	N (absorption or compression)	R, N (R290, R600, R1270, OZ-12, HC-12a)
Chillers	X	N (absorption or compression with secondary loop	X
Refrigerated Transport	N (Cryogenic system using recaptured liquid CO_2)	X	X
Commercial Ice Machines	X	N (absorption or compression)	X
Very Low Temperature Refrigeration	N	X	X

R = retrofit
N = New systems
X = not approved so far

Sources:

Refrigeration and Air Conditioning End Uses Under SNAP. Available from: http://www.epa.gov/ozone/snap/refrigerants/index.html (Accessed: December 2012)

Substitute Refrigerants Under SNAP as of August 10, 2012. Available from: http://www.epa.gov/ozone/snap/refrigerants/reflist.pdf (Accessed: December 2012)

NORTH AMERICAN POLICIES: CALIFORNIA'S REFRIGERANT MANAGEMENT PROGRAM

INTERNALIZING EXTERNAL COST OF HIGH-GWP REFRIGERANTS

The State of California has adopted the nation's first comprehensive regulation[7] 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. The 50-pound refrigerant threshold means that the rule generally applies to facilities such as:

- Supermarket and grocery stores
- Food and beverage processors
- Cold storage warehouses
- Industrial process cooling plants

On the other hand, facilities using low-GWP refrigerants are not subject to the regulation and the compliance costs it entails.

As of 2011, the regulation requires leak inspection, repairs, required service practices, and record keeping. Refrigerant leaks have to be repaired by a US EPA certified technician within 14 days of leak detection. In cases where systems cannot be repaired, a retrofit or retirement plan is required. Depending on the type and size of refrigeration system, 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 facilities.

7 Regulation for the Management of high Global Warming Potential Refrigerants for Stationary. Available from: http://www.arb.ca.gov/regact/2009/gwprmp09/finalfro.pdf"

NORTH AMERICAN POLICIES: UL STANDARDS ON HYDROCARBONS AND TRANSCRITICAL CO_2

ADDRESSING NATURAL REFRIGERANT STANDARDS

Underwriters Laboratories (UL) has developed the following requirements for the use of flammable refrigerants, including hydrocarbons in commercial refrigerators, vending machines, and room air conditioners:

- UL 250 - Household Refrigerators: Supplement SA published 25 August 2000, similar to the requirements in IEC 60335-2-24
- UL 471 - Commercial Refrigerators: Supplement SB published 24 October 2008, similar to the requirements in IEC 60335-2-89
- UL 541 - Refrigerated Vending Machines: Published requirements 30 December 2011
- UL 484 - Room Air Conditioners: Published requirements 21 October 2011, similar to the requirements in IEC 60335-2-40

The UL standards set the following refrigerant charge limits for A3 category refrigerants (including hydrocarbons) by type of application:

- Household refrigerators: 2.01oz (57grams)
- Commercial refrigerators: 5.3oz (150grams)
- Room air conditioners: 2.2lb (1kg) of propane depending on room size

Work on standards for hydrocarbons is ongoing and in February 2011, the UL's Joint Task Group on flammable refrigerants established three working groups:

- Developing requirements for flammable refrigerants for air conditioning equipment. The working group is looking at hydrocarbons for smaller, self-contained equipment, while for larger applications, the UL is working together with ASHRAE;
- Developing requirements for flammable refrigerants for refrigeration equipment. The working group is examining refrigeration equipment standards UL 563 (ice makers) and UL 621 (ice cream makers) for possible inclusion of flammable refrigerant requirements;
- To address requirements for the testing and evaluation of flammable refrigerants. The working group discusses recommended updates to UL 2182 – Safety Standard for Refrigerants.

UL is currently finalizing the certification criteria for CO_2 transcritical systems, which will enable widespread adoption of this technology in the North American market. Until then, a special permission for the placing on the market of such systems has to be received on a case-by-case basis. In addition, UL listing can be granted to specific products upon individual submissions. For example, in December 2012, one USA-based company announced that its CO_2 booster refrigeration system had received UL listing in both the US and Canada[8].

8 R744.com (2006), UL listing lifts final barrier to CO_2 transcritical use in USA supermarkets, R744.com, 13 December 2012. Available from: http://www.r744.com/news/view/3746 (Accessed: 10 January 2013)

NORTH AMERICAN POLICIES: QUÉBEC'S REFRIGERATION OPTIMIZATION PROGRAM (OPTER)

The Refrigeration Optimization Program (OPTER), administered by Québec's Ministry of Natural Resources and Wildlife, encourages large refrigeration system owners to make the switch to the more environmentally friendly types of systems that are available today.

- Supermarket component[9]: With the principal goal of reducing greenhouse gas emissions from supermarket refrigeration, the Refrigeration Optimization Program offers up to CAD$125,000 to owners of refrigeration systems in supermarkets. The program aims to promote the use of ecological refrigerants, reduce the refrigerant charge by installing secondary loops and integrate refrigeration, heating and ventilation systems.
- Ice arena component[10]: Under the Refrigeration Optimization Program (OPTER), the Energy Efficiency Agency of Québec provides support to owners of ice hockey arenas and curling rinks. It encourages them to use energy efficient refrigeration equipment during renovations or for new construction projects, to optimize refrigeration systems.

The three main objectives of the program are:

1. Optimizing heat recovery systems by integrating the refrigeration, heating, ventilation and air conditioning systems
2. Adapting the refrigeration system to climactic conditions in Québec
3. Using more environmentally safe refrigerants and reducing the amount of refrigerants in the systems

The initiative offers training to introduce managers and technicians to the ecological, energy and economic benefits of upgrading refrigeration systems. It also provides feasibility studies encompassing technical and cost-based evaluations of energy efficiency measures and means of reducing greenhouse gases from the arenas.

The program is financed as part of the PACC action plan (Action Plan on climate change 2006-2012). The government of Québec will continue the program beyond 2012, strongly encouraging installations with little or no HFCs while examining the possibility of extending the program to other sectors of application[11].

Furthermore, Québec seeks to encourage the use of low-GWP refrigerants not only through subsidies, but also by means of tightening up the provisions of the Regulation respecting halocarbons, which will be revised to broaden its scope and very strictly limit the use of HFCs in refrigeration, freezer and air conditioning equipment in the commercial sector and arenas. The new requirements will likely apply to all new systems as of 2014 and to existing installations starting in 2020[11].

9 Refrigeration Optimization Program (OPTER) – Supermarket Component. Available from: http://www.efficaciteenergetique.mrnf.gouv.qc.ca/en/business-clientele/commerce/financial-assistance-programs-for-businesses/support-for-the-manufacturing-sector/ (Accessed January 2013)

10 Refrigeration Optimization Program (OPTER) – Ice arena Component. Available from: http://www.efficaciteenergetique.mrnf.gouv.qc.ca/en/business-clientele/municipalities/financial-assistance-programs-for-municipalities/ (Accessed January 2013)

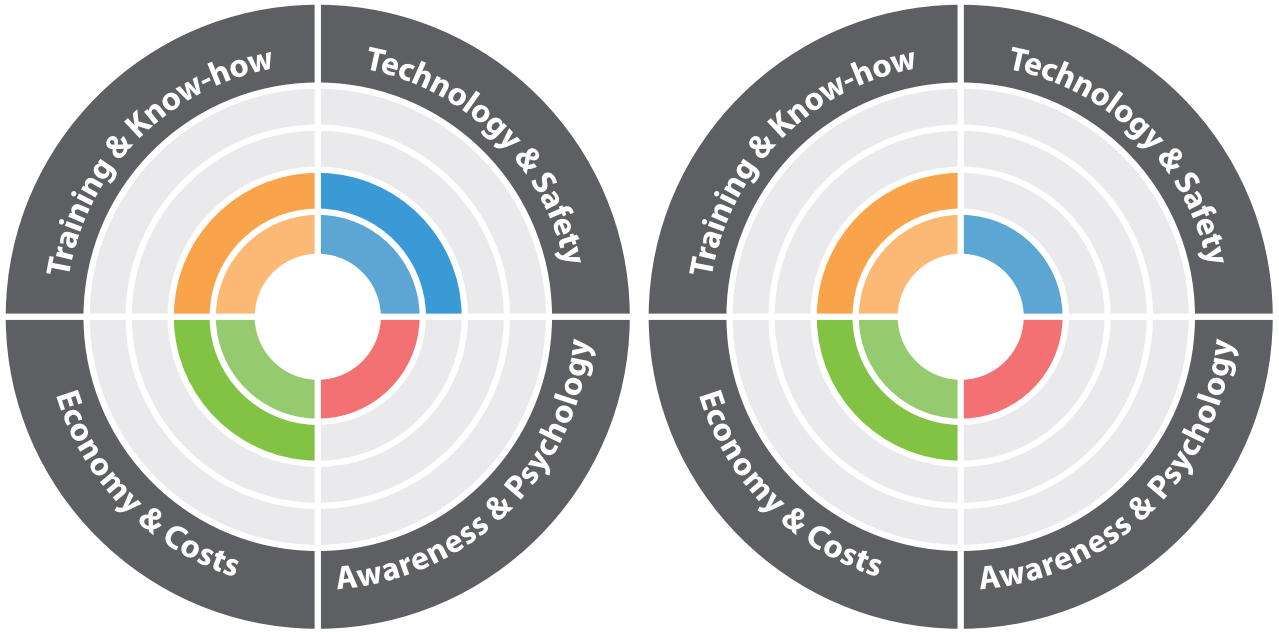
11 Québec's 2013-2020 Climate Change Action Plan. Available from: http://www.mddep.gouv.qc.ca/changements/plan_action/pacc2020-en.pdf (Accessed January 2013), page 30

US EPA 608 LEAK REPAIR REGULATIONS

Currently, there is a proposed rule for amendments[12] to the US federal §608 Leak Repair Regulations[13], a 1995 regulation addressing refrigerant leak repairs, which applies to ozone depleting substances (ODS) only. The regulations and proposed amendments do not directly address non-ODS alternatives, like R404A etc., that have been found acceptable under SNAP. Nonetheless, if these regulations are tightened, this could mean that some obsolete HCFC systems with very high leakage rates might need to be replaced earlier than foreseen. Given the high installation base of HCFC equipment in North America, this could encourage demand for new non-ODS equipment, both chemical and natural-based.

REFRIGERANT VENTING PROHIBITION UNDER US CLEAN AIR ACT TITLE VI

The Clean Air Act prohibits venting of ozone depleting substances or their substitutes. The venting prohibition therefore covers all refrigerants, including natural refrigerants and HFCs. As of 2004, the use of CO_2 as refrigerant in very low temperature and industrial process refrigeration applications is exempt from the venting prohibition. Similarly, the venting prohibition does not apply to hydrocarbons used in industrial process refrigeration systems for processing hydrocarbons[14]. Now that hydrocarbons have been deemed acceptable in domestic refrigeration and stand-alone equipment, the US EPA is looking at this particular application to determine whether or not it will take action to lift the venting prohibition for hydrocarbons in stand alone refrigeration as well[15].



12 Proposed Rule on Amendments to the Section 608 Leak Repair Requirements (December 15, 2010; 75FR 78558). Available from: http://origin.www.gpo.gov/fdsys/pkg/FR-2010-12-15/pdf/2010-31337.pdf (Accessed December 2012)

13 Section 608 of the Clean Air Act. Available from: http://www.epa.gov/air/caa/title6.html (Accessed December 2012)

14 US EPA Final Rule on Venting and Sales of Refrigerant Substitutes (March 12, 2004; 69 FR 11946). Available from: http://www.gpo.gov/fdsys/pkg/FR-1995-08-08/pdf/95-18999.pdf (Accessed March 2013)

15 hydrocarbons21.com (2009) US EPA may allow HC venting from stand-alone refrigerators, hydrocarbons21.com, 18 June 2012. Available from: http://www.hydrocarbons21.com/news/view/3257 (Accessed: 10 January 2013)

NORTH AMERICAN POLICIES: AHRI STANDARDS 571 (SI) AND 570 (I-P)

Addressing natural refrigerants in performance standards, AHRI, the USA based Air-Conditioning, Heating, and Refrigeration Institute, has published CO_2 compressor performance rating standards[16]. They are in line with the soon to be finalized corresponding standards in Europe, which are currently being reviewed in order to accommodate for the increased interest in transcritical CO_2 refrigeration in the region.

With a view toward harmonizing the rating conditions of CO_2 standards under development in Europe and China, AHRI developed Standards 571 (SI) and 570 (I-P), titled '2012 Standards for Performance Rating of Positive Displacement Carbon Dioxide Refrigerant Compressors and Compressor Units,' in cooperation with the Association of European Refrigeration Component Manufacturers (ASERCOM) and the China Refrigeration and Air-Conditioning Industry Association (CRAA). The AHRI standards, which concern CO_2 compressors for subcritical and transcritical refrigeration applications, provide, for the first time, a rating method for compressors and compressor units that use CO_2 as a refrigerant in the USA.

The new AHRI standards apply to electric motor driven, single and variable capacity, single and two stage positive displacement refrigerant compressors and compressor units operating with carbon dioxide in both subcritical and transcritical refrigeration applications.

The standards do not apply to carbon dioxide compressors used in other applications, such as heat pumps and air-conditioning, automotive air-conditioners, or household refrigerators and freezers, etc.

According to the AHRI standards, data should be reported for the intended use of compressor or compressor unit applications that meet the following conditions:

Medium Temperature (e.g. fresh food display cases)

- Suction dew point temperature, -4°F to 32°F (-20°C to 0°C)
- Discharge dew point temperature for subcritical compression cycle, 32°F to 77°F (0°C to 25°C) or discharge pressure for transcritical compression cycle, 1,160 psia to 1,595 psia (80 bar to 110 bar)
- Useful superheat of 18°F (10 K) for all operating points for subcritical applications, condenser exit subcooling of 0°F (0 K)
- For transcritical applications, gas cooler exit temperature of 95°F (35°C)
- Refrigerating Capacity may include increased refrigeration effect provided by the subcooler per rating methods of section 5.5 of the standard

Low Temperature (e.g. freezer cases)

- Suction dew point temperature, -58°F to 14°F (-50°C to -10°C)
- Discharge dew point temperature for subcritical compression cycle, 32°F to 77°F (0°C to 25°C), or discharge pressure for transcritical compression cycle, 1,160 psia to 1,595 psia (80 bar to 110 bar)
- Useful superheat of 18°F (10 K) for all operating points for subcritical applications, condenser exit subcooling of 0°F (0 K)
- For transcritical applications, gas cooler exit temperature of 95°F (35°C)
- Refrigerating Capacity may include increased refrigeration effect provided by the subcooler per rating methods of section 5.5 of the standard

The aligned standards establish common guidelines worldwide and will enable manufacturers to compare compressor behavior and performance on an even-across-the-board basis.

16 AHRI (2012), 2012 Standards for Performance Rating of Positive Displacement Carbon Dioxide Refrigerant Compressors and Compressor Units, AHRI Standards 571 (SI) and 570 (I-P). Available from: http://www.ahrinet.org/ahri+standard+571+_si_2012_+performance+rating+of+positive+displacement+carbon+dioxide+refrigerant+compressors+and+compressor+units.aspx and http://www.ahrinet.org/ahri+standard+570+_i_p_2012_+performance+rating+of+positive+displacement+carbon+dioxide+refrigerant+compressors+and+compressor+units.aspx (Accessed: January 2013)

NORTH AMERICAN POLICIES: US EPA GREENCHILL PARTNERSHIP

GreenChill[17] is an EPA partnership with food retailers, which encourages them to reduce refrigerant emissions and decrease their impact on the ozone layer and climate change. The Partnership works to help food retailers transition to environmentally friendlier refrigerants, lower their refrigerant charge sizes, eliminate leaks, adopt green refrigeration technologies and environmental best practices, through three main programs:

- Corporate Emissions Reduction Program
- The Store Certification Program
- The Advanced Refrigeration Program

GreenChill Partners include food retailers, manufacturers of advanced refrigeration systems, and manufacturers of retrofit chemicals and secondary fluids. Several participating retailers already use cascade refrigeration systems with CO_2, including CO_2/NH_3 cascade systems, or CO_2 as secondary refrigerant, and have been rewarded for their efforts. At the 2012 Environmental Achievement Awards by the GreenChill Partnership, an all-natural refrigerant store in California, which featured both an ammonia primary system, located in an outdoor enclosure, that condensed CO_2, as well as propane self-contained merchandisers, was honored with the prestigious 'Best of the Best Award'. Moreover, the USA Department of Energy has used this same store to highlight its national 'Better Buildings Challenge'- program, which was launched by President Barack Obama in December 2011. The supermarket in Carpinteria is expected to deliver 30% lower energy bills as compared to a traditional store[18].

Five years after its launch, the GreenChill Partnership makes up over 20% of stores in the USA, representing more than 8,000 supermarkets in all 50 states and Washington, DC.

As a result of GreenChill's Partners' activities, the amount of avoided HFC emissions has increased from 1.53 million metric tons of CO_2eq ($MMTCO_2eq$) in 2007 to 4.12 $MMTCO_2eq$ in 2011. The avoided emissions from ozone depleting substances (ODS) and HFCs combined increased from 2.99 $MMTCO_2eq$ in 2007 to 6.21 $MMTCO_2eq$ in 2011[19].

17 US EPA GreenChill Partnership, http://www.epa.gov/greenchill

18 US Department of Energy (2012), Better Buildings Challenge. Available from: http://www4.eere.energy.gov/challenge/showcase/supervalu/albertsons-carpinteria-remodel (Accessed: March 2013)

19 US EPA (2012), GreenChill Progress Report. Available from: http://www.epa.gov/greenchill/downloads/GreenChill_ProgressReport2011_2012-09-24.pdf (Accessed: December 2012)

NORTH AMERICAN POLICIES: CANADA'S REVISED ENVIRONMENTAL CODE OF PRACTICE FOR ELIMINATION OF FLUOROCARBON EMISSIONS FROM REFRIGERATION AND AIR CONDITIONING SYSTEMS

Now recognizing natural refrigerants in refrigerant codes of practice, Environment Canada is expected to publish a revised Refrigerant Code of Practice[20] that addresses the design, installation, operation, servicing, maintenance, and decommissioning of cooling systems. The draft version of the revised Code updates the phase-out of CFCs and HCFCs, the best practice technologies, and techniques for reducing emissions of refrigerants. It also considers the global warming implications of refrigerants and their use. According to the draft version of the code, the passages "with respect to existing and proposed non-halocarbon refrigerants such as ammonia, carbon dioxide (CO_2) and hydrocarbons (HC) may be useful and provide alternatives to leapfrog over HFCs in transitions from HCFCs directly to more sustainable solutions". For the first time, the draft code recognizes the wide and expanding use of ammonia as the leading refrigerant for cold storage, food processing, and ice arenas, and provides recommendations on the safe handling of hydrocarbons.size in the country, at least 30% lower than a traditional store.

20 Environment Canada (2011), Draft Environmental Code of Practice for Elimination of Fluorocarbon Emissions from Refrigeration and Air Conditioning Systems. Available from: http://www.ec.gc.ca/Air/E702A47B-BAE8-49D0-A83F-5B9B0C337777/Code_of_Practice.pdf (Accessed: January 2013)

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The CD RANGE, for transcritical applications, represent the most advanced solution the market is actually having. The innovative design allows the specific fluidodynamic of internal pathways to grant the maximum results during the compression process, minimizing the thermal levels and the pressure loss. This thanks to the matching of high tech solutions with a carful engineering with an eye to cost control. Reduction of the GWP coefficient, maximum reliability and extreme efficiency: these are the guidelines that generated the new CD RANGE, ideal solution to any type of system that keeps in its values the respect of the environment.

HEX SERIES

As far as natural refrigerants are still concerned, the ATEX range is launched into the market as an excellent solution for explosion-proof applications to be used both with inflammable fluids (propane and propylene) and traditional refrigerants. The _ATEX range_ respects the soul, the reliability and the efficiency of the H range, but by means of specific technical processings, it allows to manage, in a total safety condition, the problems concerning the inflammability of the refrigerant or of the atmosphere surrounding the compressor. You have to notice that hydrocarbons (HC) allow high compression energy performances, have a null ODP and very low GWPs in case of leakages from the plant. Propane and propylene are refrigerants that are benefiting of regulations providing the Phase-out of old refrigerants and are being very successful in A/C applications and in the mean temperature refrigeration.

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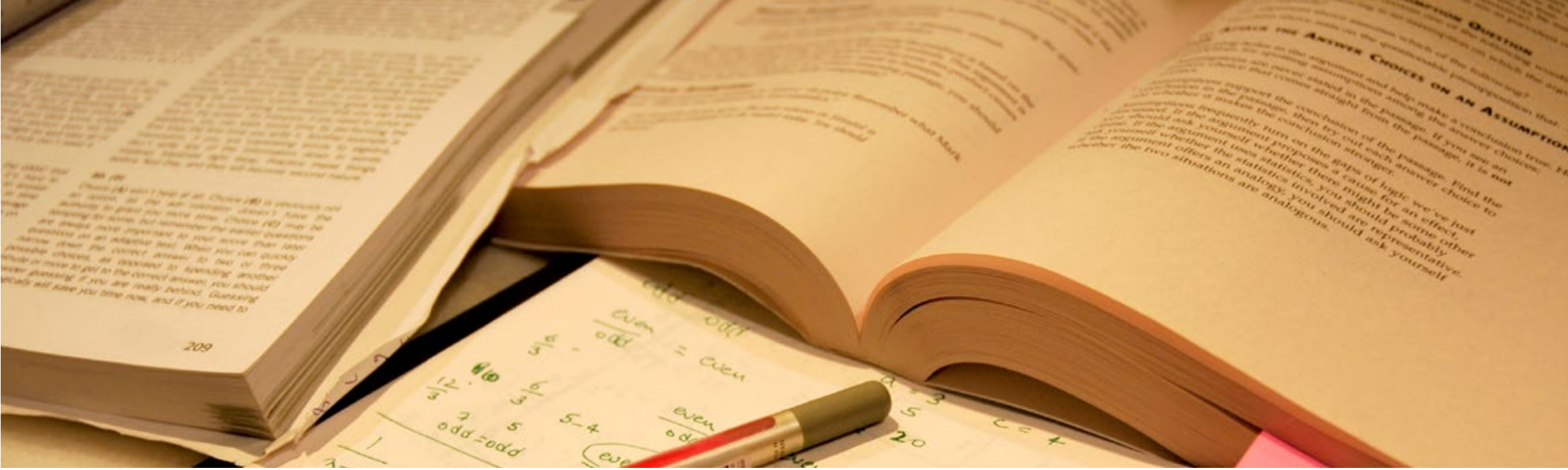

CASE STUDIES

Real-life examples of successfully working technologies are the strongest arguments for spreading innovative solutions, engaging legislators and convincing end-users. From the multitude of existing natural refrigerant-based systems, this section presents a selection of outstanding examples, covering residential, commercial and industrial heating, air-conditioning and refrigeration solutions.

Examples cover North American-based suppliers including: Carnot's efficient CO_2 transcritical refrigeration technology installation for retailer Sobeys and their NH_3/CO_2 refrigeration system for a food storage warehouse and CO_2 ice rink refrigeration system, (both in Canada); Emerson's energy saving industrial ammonia heat pump for heat recovery at a food processing plant; the latest Dorin CO_2 transcritical compressors; CIMCO's CO_2/ammonia brine system for a Canadawide fruit and vegetable distribution center; Alfa Laval's CO_2 refrigeration systems for retailer S-Market; MYCOM's CO_2 hot water heat pump at the Somerston Wine Co. and their ammonia/CO_2 chiller at the Carpinteria SUPERVALU store, (both in California); Danfoss and Manitowoc's collaborative effort to develop hydrocarbon ice machines, and Hill PHOENIX's CO_2 refrigeration system installation at the Overwaitea Food Group (OFG) Urban Fare Express store in Canada.

TRANSCRITICAL CO_2 SOLUTION AS A REPLACEMENT TO HFCs IN SUPERMARKETS

ABOUT THE COMPANY

Since 2008, Carnot Refrigeration has lead the CO_2 market in Canada. The company offers integrated services for the design, manufacturing, and installation of high quality and eco-efficient CO_2 systems for supermarkets, industrial applications, and ice rinks.

More information at:
www.carnotrefrigeration.com

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INTRODUCTION

For the past several years, Carnot's services have been retained by Sobeys (a major wholesaler and retailer in Canada) in order to develop an alternative to the conventional refrigeration systems available on the market, which were inefficient, had a high energy consumption, and incurred high maintenance costs.

The goal was to provide a sustainable and reliable solution that would be cost efficient in regards to both initial cost (equipment and installation) and operating cost (energy, maintenance, gas replacement, insurance).

ABOUT THE SYSTEM

An IGA supermarket (part of Sobeys' brand) in the north of Montreal, which opened in April 2011, occupies a total area of 40,866 ft^2 (3,797 m^2). The sales area of 30,488 ft^2 (2,832 m^2) hold 744 ft (227 m) of refrigeration cases (85 MT cases) and 305 ft (93 m) of freezers (40 BT cases). The supermarket also has a heat recovery system and intensive reclaiming of waste heat from the refrigeration units. That recovery system covers almost all the heating needs of the supermarket. A pre-heating water loop is also installed in the supermarket.

Defrosting modes

Because it does not add any heat to the system, the technology that was developed in previous commercial and industrial projects provides the significant benefit of ensuring the stability of display case temperatures, unlike some other systems that may generate high temperatures in display cases. Using our system, we have often observed that the temperature only rises from 4°C (39°F) to 5°C (41°F).

In the low temperature defrost process for refrigerated cases and freezer rooms, Carnot Refrigeration technology uses an electronic expansion valve that expands or contracts in real time to provide exactly the right amount of heat needed by each case to melt the ice.

Low pressure gas is used (about 440 to 500 psig) to defrost the refrigerated cases and the evaporators of the freezer rooms. During the defrost cycle, the same lines are used for the refrigeration cycle. In refrigeration mode, liquid CO_2 is directed to the display

cases through an oversized line. In defrost mode, the hot gas is directed straight to the display cases using the liquid line.

In summary, the biggest advantage of the hot gas defrost in CO_2 refrigeration systems is the stability and the homogeneity of the temperature levels in display cases, freezer and preparation rooms.

CONCLUSION

Nowadays, transcritical CO_2 refrigeration technology is a proven technology in Canada. The systems installed by Carnot Refrigeration in various supermarkets, are evidence of this. In fact, the GHG emissions are lower than those from a conventional supermarket of the same size. These gains are attributable to the reduction of synthetic refrigerant charges and the decrease of the total energy consumption (-10%). In addition, the heating of the sales area is provided entirely through heat recovery. The interesting thing about the new systems is that CO_2 as refrigerant is used in connection with both medium and low temperature.

After several successful transcritical CO_2 refrigeration system installations in many supermarkets across Canada, the various solutions developed by Carnot are now available for all retailers operating in North America. Carnot also helps the retailers to smoothly introduce this new technology and manages the teams that will be faced with the technology change.

CARNOT
REFRIGERATION

NH_3/CO_2 REFRIGERATION SYSTEM AT COURCHESNE LAROSE (MICHAL INC.)

ABOUT THE COMPANY

Since 2008, Carnot Refrigeration has been leading the CO_2 market in Canada. The company offers integrated services for the design, manufacturing and installation of high quality and eco-efficient CO_2 systems for supermarkets, industrial applications and ice rinks.

More information at:
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INTRODUCTION

The major task of food processing applications is to ensure the freshness of perishable goods. Storages are used to smooth out peaks and troughs in production, allowing a more continuous supply to customers and helping to maintain the quality of produce.

The warehouse of Courchesne Larose (Michal Inc.) is spread over an area of 100,000 ft^2 with a 40 ft. height, able to accommodate 2,069,945 kg (4 563 442 lbs) of food per day. It includes 22 ripening rooms for bananas, a main dock with 19 garage doors, and a banana dock with 3 garage doors. The temperature in the rooms varies between 0 and 15°C (32 to 59°F).

Carnot Refrigeration Inc. has designed and manufactured an ideal system for this warehouse. Their NH_3/CO_2 refrigeration system provides a significant advantage because it greatly minimizes environmental impact. Although this system is very new, it should be emphasized that Carnot Refrigeration Inc. has integrated innovative new technologies, for instance the total recovery of the heat rejected by compressors.

ABOUT THE SYSTEM

The major advantages of this technology are summarized as follows:

- Completely eliminates the use of HFCs and / or HCFCs
- Reduces the ammonia quantity drastically without energy penalty
- Reduces piping and insulation size by more than half and the related labour and material cost by 31.5%
- Reduces the use of paraseismic hangers and the structural need to support the pipes
- Ammonia is confined to the mechanical room.
- Provides full heat reclaim (if needed) for space heating or water heating (domestic or process)

Hot gas defrost

The hot gas provides a quick and efficient evaporator defrost. Compared to electric defrost, this method has the advantage of zero additional energy expenditure or adding heat in the energy balance of the system.

The hot gas defrost offers the possibility to heat the docks and all other areas of the warehouse as needed, always without additional energy expenditure and no additional mechanical equipment (pumps, loop glycol, heaters, etc.).

Heat recovery

The NH_3/CO_2 refrigeration system is designed to recover direct heat from the discharge gases of the CO_2 compressors to fuel recovery coils and to heat the ambient air of offices and warehouse spaces, such as the shipping dock and work shop, which require heat. This option provides recovery capacity (available heat) up to 8 times greater than the use of an intermediate loop glycol.

TFC – Mode « Free Cooling »

Using CO_2 by direct expansion in cascade with ammonia, our system employs the TFC mode (free cooling) when the outside temperature is below 8°C. This mode is maintained for 4000 hours in the Montreal area.

During the hours of TFC mode, NH_3 compressors remain completely stopped. These breaks increase the lifetime of the compressors, the lubrication system, and other components of the ammonia loop.

In comparison, for a recirculation loop with CO_2 kept at -8°C, outside temperature must remain below -15°C to allow for the TFC mode. It corresponds to a potential of 250 in the Montreal area. We expect that this system will reduce the total energy (kWh) requirement of the building, compared to a direct NH_3 system.

CARNOT
REFRIGERATION

CARNOT'S ICE RINK REFRIGERATION SYSTEM, CO_2OL SERIES

CARNOT REFRIGERATION

ABOUT THE COMPANY

Since 2008, Carnot Refrigeration has been leading the CO_2 market in Canada. The company offers integrated services for the design, manufacturing and installation of high quality and eco-efficient CO_2 systems for supermarkets, industrial applications and ice rinks.

More information at:
www.carnotrefrigeration.com

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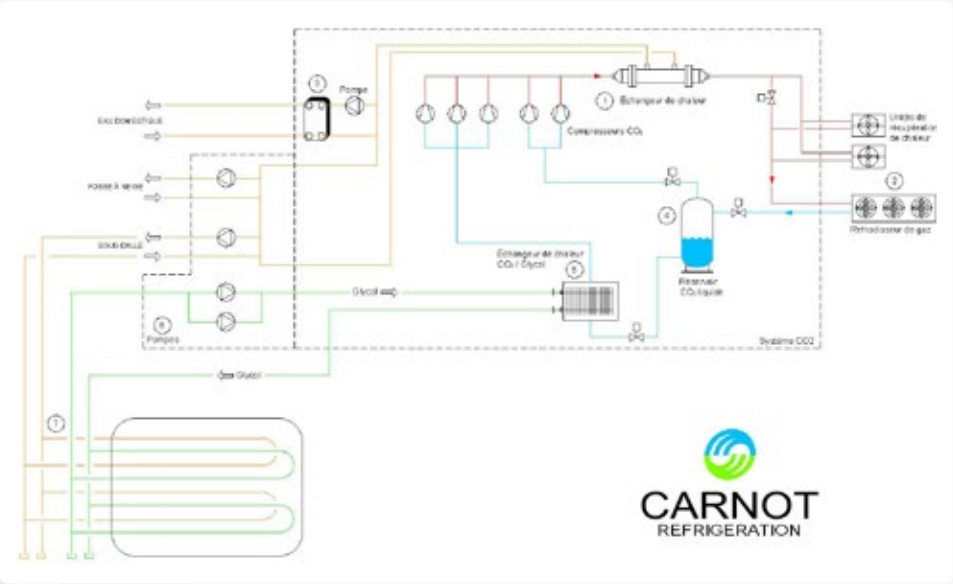
INTRODUCTION

After having deployed an alternative solution for the supermarket and industrial world, Carnot is now providing a very attractive (cost & safety wise) alternative to ammonia or HFC refrigeration systems used for recreational ice rinks.

ABOUT THE SYSTEM

- Natural and non-toxic refrigerant
- GWP = 1.0 / ODP=0
- No need for fixed machinery mechanics (FMM)
- Does not require any major change in the mechanical room
- Possibility to reuse existing pumps and piping for the brine/glycol closed loop
- Reliable and proven systems
- Very safe, industrial grade product
- Maintains pressure and workload during a prolonged stop
- Increased energy efficiency
- Simple, factory manufactured system
- Compact and lightweight gas cooler
- Replacement parts available from common distributors

CASE STUDY



Description of the CO_2 transcritical refrigeration systems

1- Compressor and Desuperheater

This is the cooling stage in which the pressure is lowered to increase efficiency. We use the direct heat recovery from the CO_2, using stainless steel piping. The heat generated by the refrigerant's compression is sent to the desuperheater to warm up the hot water closed loop, which feeds the subfloor, the snow pit, etc.

2- Direct heat recovery

The unused heat from the desuperheater is sent to the arena heat recovery units. When the heat recovery is not needed, the refrigerant is sent to the gas cooler (condenser).

3- Domestic hot water exchanger

This is used to preheat domestic hot water.

4- Liquid CO_2 tank

The purpose of this tank is to control the level of the liquid refrigerant, which changes during the use of the system. It also feeds the exchanger with CO_2 / Glycol or brine.

5- Exchanger CO_2 / Glycol or brine

At this stage, the heat transfer fluid is cooled to the preset value to maintain the quality of ice required. The exchanger is specifically designed to be used with CO_2 / Glycol or brine.

6- Glycol/brine circulation pumps

The CO_2OL systems from Carnot Refrigeration have the flexibility to be used with existing circulation pumps, or new ones can be installed to meet customer needs.

7- Distribution system slab and subfloor

As for the circulation pumps, the existing distribution systems for the slab and subfloor can be kept and re-used. To protect the heat transfer fluid closed loop against corrosion and erosion, Carnot's systems can be equipped with a water treatment.

SUMMARY

In conclusion, the compactness, combined with the simplicity of the CO_2 transcritical solution provided by Carnot Refrigeration allows important savings (capex & opex). The system using CO_2 is the safest solution (for humans and the environment) that is available for recreational ice rinks.

CARNOT
REFRIGERATION

INDUSTRIAL HEAT PUMP AT FOOD PROCESSING PLANT

ABOUT THE COMPANY

Emerson Climate Technologies, a business segment of Emerson, is a world leading provider 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.

More information at:
www.emersonclimate.com

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INTRODUCTION

A major food processing plant in Iowa made significant investments in energy conservation. With a focus on energy savings, the plant installed high efficiency boilers and invested in the capture and recover of boiler stack heat. Yet, like many food processing plants, they were paying for electrical energy to remove heat from their refrigerated spaces with an ammonia refrigeration system and rejecting that heat to the atmosphere. Also, they were paying for natural gas to add heat to hot water used for the hygienic cleaning of the plant.

If the rejected heat could be captured and used to provide water heating, substantial energy would be saved. The highest pressures and temperatures in the refrigeration system (compressor discharge gas) provided the best source for heat to be transferred to the sanitation clean-up water. But, as ammonia refrigeration practitioners who have employed "heat reclaim" practices have noted, ammonia at typical condensing pressures, while possessing large quantities of heat energy, condenses at fairly low temperatures [75-95°F (24-35°C)]. The transfer of this energy to city water, through conventional heat exchangers, to create 145-185°F (63-85°C) wash down water, is only effective for limited pre-heating of the cold water supply.

If the refrigeration system compressor discharge gas, at fairly high pressures [180 psig (13.2 atm)] could be fed directly into the suction of a "heat pump" compressor and compressed to even higher pressures [i.e. 450-800 psig (32-55 atm)], condensing this higher pressure ammonia with cold water in a heat exchanger would capture much larger quantities of heat energy than heat reclaim and would elevate the cold water supply from 60°F (15°C) up to the 145°F (63°C) required for wash down.

The requirement of the plant to have the wash down water classified as a potable supply presented another challenge, as local codes prohibit potable water to be in direct heat exchange with ammonia. Using such an ammonia heat pump system would require a secondary loop, thereby lowering the efficiency of heat transfer.

Given the need for sustainable projects to clear the same internal rate of return hurdle as non-sustainable projects, the challenge was to define and justify the project. The project costs would include tapping into the ammonia refrigeration system, adding and installing a custom ammonia heat pump system and employing the electrical energy to operate the high pressure ammonia heat pump system.

ABOUT THE SYSTEM

The ammonia heat pump system delivers hot water at 145°F using the heat extracted from refrigeration. It features Vilter™ single screw compressors. The inherent high pressure capability of the single screw compressor allows for full acceptance of the highest operating discharge pressure from the host system, even in excess of 180 psig, without the risk of rotor deflection and excessive bearing thrust loads, which can result in accelerated degradation or the loss of efficiency due to over-compression.

With the lower 60°F (15.6°C) incoming cold water temperature during winter, the estimated heating capacity of the heat pump during winter conditions was estimated at 5.738 MMBtuh (1,682 kW), providing 135 GPM (30.7 m^3/h) of continuous 145°F (62.8°C) hot water flow. The heat pump was estimated to provide an average year-round heating capacity of 7.013 MMBtuh (2,056 kW), heating 170 GPM (38.6 m^3/h) from 62.5°F (16.9°C) to145°F (62.8°C).

Since its commissioning, the plant heats 170 gallons of water per minute. This hot water is delivered far more efficiently than the water from their natural gas hot water heater. The ammonia heat pump solution has cut heat energy cost by over $250,000 each year and saves fourteen million gallons of water per year because of the reduced load on the evaporative condensers.

By using ammonia, Emerson's compressor technology solution offers a refrigerant with a good environmental profile (non-ozone depleting and zero global warming impact) that delivers higher temperatures and provides superior performance benefits from its consumed resources, than competing technologies. In addition, the balanced radial and axial force design of the single screw compressor lowers stress on the unit's bearings, resulting in low operating and maintenance costs, while delivering a performance unachievable with any other type of compressor.

"The heat pump automatically responds to varying operating conditions for the ammonia and hot water. There is very little input needed from the operators. Maintenance requirements are really no different than what is already required for existing compressors, vessels and heat exchangers. Between the boiler stack gas heat recovery and the heat pump, we no longer use the conventional hot water heaters on a daily basis."

- Infrastructure Program Manager

RESULTS

- Annual operational savings of $267,407
- 14,000,000 gallons of water saved annually
- Waste heat recovery of 7.0 MMBtuh (2.1 MW)
- 6.51 coefficient of performance (summer)
- 4.23 coefficient of performance (winter)
- Ammonia refrigerant with 0=ODP & 0=GWP
- 15% higher efficiency than comparable technologies
- Design for +20 years service without costly maintenance

Learn more about industrial heat pump systems, featuring Vilter single screw compressors at emersonclimate.com/industrialheatpumps

EMERSON
Climate Technologies

LATEST DORIN CO_2 TRANSCRITICAL COMPRESSORS

ABOUT THE COMPANY

Dorin entered the field of refrigeration in 1932 with its first open-drive compressor range. The first CO_2 transcritical type was commissioned in 1999. Today, Dorin produces more than 70,000 compressors per year.

More information at:
www.dorin.com

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INTRODUCTION

Carbon dioxide (R744 - CO_2) is nowadays considered one of the most attractive long-term solutions for commercial and industrial refrigeration applications, as well as for hot water heat pumps.

To meet the growing demand for CO_2 technology the Italian compressor specialist has developed a new semi-hermetic reciprocating compressor range and a new semi-hermetic reciprocating compressor model, both for CO_2 transcritical applications.

ABOUT THE SYSTEMS

CD-2S RANGE

The new CD-2S range offers the capability to work with extreme pressure ratios, permitting the use of typical CO_2 low temperature equipment without the need to implement a cascade or a booster arrangement, thus drastically cutting the risk of failure intrinsically present in any booster or cascade application.

The CD-2S range represents the latest, cutting-edge development for transcritical CO_2 compressors. These models can be used in a wide range of applications. They provide several operational benefits:

- The ability to handle large pressure differences produced by typical direct expansion low temperature systems configuration (T_ev = -35°C or -31°F), rejecting the heat directly to the ambient (up to 100 bar discharge pressure), thus providing an intrinsically safer installation. In fact, in a booster system, any failure occurring on the low pressure side will automatically be reflected into the high pressure side, and vice-versa.
- Issues related to stand-still conditions become obsolete, at least regarding compressors, as the compressors have Pss = 100 bar.
- Increased system efficiency of medium temperature equipment (T_ev = -10°C or 14°F) located in warmer areas by using the sub-cooling effect obtainable through a very simple inter-stage gas heat exchange with a gas cooler outlet. This could clearly boost the installation's energy efficiency, making CO_2 a viable solution, also for warmer climates (e.g. Southern Europe).

- Safe operating of a CO_2 heat pump down to extremely low ambient temperatures (T_amb = -25°C or -13°F) with no need for additional electric heaters, thus boosting the equipment's efficiency.

Main Characteristics

- Semi-hermetic reciprocating compressor
- Generous electric motor sizing
- Max. standstill pressure: 100 bar, top figure within competition products
- Displacement (m^3/h at 50Hz): 11.6 – 15.1 m^3/h
- Cylinders: 4
- Suitable for frequency control regulation, up to 75Hz

Advantages

- Room opening for LT applications with single stage compressor with no need for a booster / cascade arrangement: intrinsically safer installation
- Standstill pressure boosted to 100 bar, allowing:
- No issues during prolonged standstill
- Safer preservation of goods
- Extra-robust drive gear for extreme and proven reliability
- Multi-layer, self lubricating bearing for superb robustness against liquid slugging
- Silent and smooth operation in any operating condition
- Wide application envelope to suite all possible applications and systems
- Utmost reliability
- Utmost COP levels

CD5000M

With its 30.5 m^3/h displacement, the new CD5000M is able to work in typical medium-low temperature applications and allow for the consistent decrease of the number of compressors assembled on racks, thus leading to consistent cost reduction for end-users.

CD5000M represents the last extension of the well known and appreciated CD400 range. At the time, the CD400 range already featured the largest CO_2 transcritical model commercially available on the market (namely CD4000H, 26.5 m^3/h). With the introduction of CD5000M, DORIN has further strengthened its leading position in the market, allowing its business partners to provide the best solution for end users.

Main Characteristics

- Semi-hermetic reciprocating compressor
- Electric motor specifically sized for CO_2 applications
- Max. standstill pressure: 100 bar, top figure within competition products
- Displacement (m^3/h at 50Hz): 30.5 m^3/h
- Cylinders: 4
- Suitable for frequency control regulation

Advantages

- Possibility to reduce the number of compressors in typical rack systems
- Sensible cost reduction for end users
- Standstill pressure boosted to 100 bar, allowing:
  - » Prolonged refrigerant containment during long-lasting standstill
  - » Safer good preservation
- Extra-robust drive gear for extreme and proven reliability
- Multi-layer self lubricating bearing for superb robustness against liquid slugging
- Silent and smooth operation in any operating condition
- Wide application envelope to suit all possible applications and systems
- Utmost reliability
- Utmost COP levels

CO_2 / AMMONIA BRINE SYSTEM FOR DISTRIBUTION CENTER

ABOUT THE COMPANY

Over the years, CIMCO has grown into an international refrigeration leader in the industrial refrigeration food and beverage and cold storage markets. The Canadian Ice Machine Company, now known as CIMCO, was purchased by Toromont Industries Ltd, a publicly traded company, in 1969. Today, CIMCO's specialties include the full spectrum of engineering, designing, manufacturing, installing, and servicing of industrial, process cooling and recreational refrigeration systems.

More information at:
www.cimcorefrigeration.com

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INTRODUCTION

CIMCO's specialties were fully utilized when it was challenged by Canadawide to design an ammonia/CO_2 system for Canadawide's growing distribution center. This case study looks at Canadawide's expansion and its new state of the art refrigeration system, installed at its Montreal warehouse.

Canadawide is a national wholesaler of fruits and vegetables. The company history is as follows:

- 1961 - Green Grocery is founded by Greek immigrant John Pitsikoulis as a grocery store in Montreal, focusing on top quality produce to local clientele
- 1960's- Green Grocery expands to several locations throughout Montreal
- 1979 – First 15,000 sq. ft. warehouse is opened
- 1983 – Name is changed to Canadawide to increase emphasis on the company as a distributor
- 1989 – Retail division is sold to focus on the wholesale division
- 2001 – Canadawide establishes its premises at the Marche Central. This location is refrigerated by R-22.
- 2011- Canadawide undertakes an expansion of a brand new cold storage.

Original Specification

The original specification was based on a Freon/glycol system. The client's objectives were to install a system with the following criteria:

- Lowest annual operating costs
- Lowest maintenance costs
- Increased efficiency/heat reclaim
- Employee comfort
- Maintain a timely construction schedule

The cold storage building has a total capacity of 984 kW with the following layout

- 5,575 m^2 (60,009 sq. ft.) of refrigerated space
- 8 coolers from -4°C to 5°C (24.8 to 41°F)
- 17 door loading docks
- 8 banana rooms

- 3 process rooms with personel
- Dry storage
- Fresh air for the process rooms

Although R-22/Glycol was initially preferred, other approaches, such as direct ammonia, Freon commercial, and ammonia/secondary fluid loop, were considered. However, despite its original preference, Canadawide found that an ammonia/CO_2 brine system would actually align best with their objectives. The contract was awarded to CIMCO in December 2011, with the intent to be operational by April 2012.

ABOUT THE SYSTEM

The designed system uses medium temperature ammonia as the primary refrigerant to cool a single loop of re-circulated CO_2 which feeds the various evaporators.

The mechanical room, located on the second floor, is 6 x 14m (19.7 x 45.9ft) and has a height restriction of 3.9m (12.7ft) under the beams.

To respect the provincial refrigeration code requirements, two 150 kW industrial screw compressors, with ammonia evaporation at -11°C (51.8°F) and ammonia condensation at 35°C (95°F) were selected. In order to increase efficiency, the screws utilize the economizer port to sub-cool the liquid. The heat is rejected via an evaporative cooled condenser located outside, slightly above the mechanical rooms. The condenser was selected with a low-height centrifugal motor, to accomodate the architectural constraints of a 3m (9.8ft) roof height. An internal water sump tank and pump is used because of the rigorous winter conditions in the area. To limit the refrigerant change, the system was designed with a critical charge of ammonia. A high side pressure float feed is used for the ammonia/CO_2 cascade cooler.

Considering the height limitations, a CIMCO shell and tube one-pass cascade cooler with an increased length was selected, in order to have the minimal diameter size. To keep the efficiency of the system as high as possible, the temperature difference is lower than the average 4.4°C (39.9°F), producing CO_2 at -6.6°C (20.12°F). The CO_2 pump receiver is located directly underneath the heat exchanger and low static head CO_2 pump is utilized. The CO_2 is pumped in the main distribution loop for the entire facility. The main CO_2 collector for liquid is 100mm (3.93 inches). The piping located in the mechanical room is all carbon steel, high pressure welding, while the CO_2 piping in the cold storage area is stainless steel.

Each refrigeration evaporator is equipped with modular valve assemblies. The higher temperature 7°C (44.6°F) rooms use ambient air defrost, while the lower temperature rooms are equipped with electric defrost. Since the entire system is fed via one loop of recirculated CO_2 at -6.6°C (20.1°F), special care had to be taken to minimize the dehydration of the higher temperature rooms with greater operating TD. Special modulating liquid solenoid valves were installed for those applications.

Additionally, the banana room has special requirements to insure quality of the product. Conscious about providing the customer with the best performance and most reliable system, CIMCO installed a plate and frame ammonia/glycol cooler to provide the cooling for the banana room evaporators. This special feature allows the system to operate at a higher temperature, respecting the temperature limit for ensuring the safe preservation of the product.

Safety:

One of the safety concerns associated with CO_2 is the high pressure throughout the system. CIMCO mitigated the safety risks by installing the following safety features:

- High pressure pipe burst: Installed relief valves at critical points for controlled release
- Ammonia system electrical failure: Installed a 3 kW R-404A condensing unit on the CO_2 re-circulator to keep the pressure at the design conditions of 40 bar.

Piping Costs:

CO_2 systems require a higher grade piping due to the higher pressures. Compared to traditional systems, the higher priced piping is offset by smaller diameter size, faster onsite installation, easier layout of the piping route, and less thermal insulation.

Performance:

The complete system has been operating for several months now, and CIMCO is pleased to report that the monthly energy consumption is lower than the original Freon design. More importantly, the room temperature is perfectly maintained, and the humidity level is within the expected levels. The owner had expressed his complete satisfaction, and is planning on using the same design for his phase two expansion.

During the start up procedure, Patrick Ianniciello, the Project Manager, made the following comments:

> *"In my entire career I have never seen room temperatures going down so fast, this system is operating like crazy, and I would recommend this system over any other I've seen."*

CIMCO is pleased to have been the design-build supplier and installer of this innovative and energy efficient ammonia/CO_2 system. This allowed the company to demonstrated that the CIMCO system is a viable alternative, when a direct ammonia system is not the desired option.

ALFA LAVAL'S CO_2 REFRIGERATION SYSTEM AT THE S-MARKET BUILIDNG IN HELSINKI, FINLAND

ABOUT THE COMPANY

Alfa Laval is a leading global provider of specialized products and engineered solutions. The company's equipment, systems, and services are dedicated to helping customers optimize the performance of their processes. The Condensers, evaporators, and gas coolers by Alfa Laval make transcritical CO_2 and cascading systems responsible, efficient, reliable, and safe. Alfa Laval has the products for and expertise on applications ranging from an air cooler to a complete transcritical CO_2 solution with heat recovery. Alfa Laval's worldwide organization works closely with customers in almost 100 countries.

More information at:
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INTRODUCTION

At the new S-Market building in Helsinki, Finland, cooling and terminal rooms are full of evaporators labeled and manufactured by Alfa Laval. The company was able to help S-Market become one of the few supermarkets in Finland that use CO_2 refrigerant.

"In this very interesting project, our customer, the S-Group, gave us a few prerequisites for the type of cooling equipment they wanted. The most crucial requirement was carbon dioxide, which had to be chosen as the refrigerant," says Taisto Tolonen, Project Manager at Norpe Finland, the company that installed the supermarket's cooling system. " The most commonly used refrigerant in Finnish supermarkets is still artificial. The challenge is that it does not meet the upcoming F-gas legislation, which will be enforced in a few years."

Currently, there are no more than 50 supermarkets in Finland using carbon dioxide as a refrigerant. According to Tolonen, Norpe and Alfa Laval have been cooperating since the 1970s. This latest project started with a visit to Alfa Laval in Italy in December 2011, where the carbon dioxide evaporators are manufactured. "Although carbon dioxide is nature's own gas, it does not act like traditional, more commonly used refrigerants," says Hannu Viikilä, Alfa Laval Nordic project owner.

ABOUT THE SYSTEM

S-Market's cooling system includes an Optigo CC air heat exchanger in the freezer, and Optigo CD coolers in the fish, chicken, ready-food, fruit, and vegetable cold storage rooms. Both models are part of Alfa Laval's Optigo range of energy-efficient and environmentally friendly air heat exchangers.

There are currently three models available in the range which have been optimized for CO_2 and are easy to install, making them ideal for small to medium commercial applications, such as supermarkets, restaurants, and chilled food storage.

Optigo CD

For cooling and freezing rooms, where high activity demands increased airflow, the Optigo CD provides double airflow as well as low air velocity and noise levels. As with the other products in the Alfa Laval's Optigo product line, the CD model is easy to install, clean and follows HACCP guidelines for food safety.

S-Market's cooling system consists of one Optigo CD cooler in the fish cold room (0-2°C or 32-35.6°F), chicken cold room (0-2°C or 32-35.6°F), ready-food cold room (3-5°C or 37.4-41°F), fruit and vegetable cold room (6-8°C or 42.8-46.4°F), as well as three coolers in the terminal area (2-4°C or 35.6-39.2°F).

Optigo CC

Optigo CC is the perfect single flux choice for larger-volume applications. It has a clever design with a new, highly efficient coil (for reduced refrigerant content) and the same footprint as the previous series. This makes it easy to install and connect, while high-energy efficiency gives low lifecycle costs. An Optigo CC has been installed in S-Market's freezing room (-20 to -18°C or -4 to -0.4°F).

RESULT

"In order to guarantee the highest possible quality of our products, we tested certain units and then created design programs with which to secure exact capacities," says Hannu Viikilä. Carbon dioxide has good heat exchanging abilities, but its draw back has always been its high pressures. However, Viikilä points to the isolated bunker that Alfa Laval built at its manufacturing site in Alonte, Italy, where long gas coolers can be pressure tested with 172 bar.

"I can proudly say that our clear strength is the ability to combine theory and praxis," adds Hannu Viikilä. "We are able to show how carbon dioxide reacts at different pressures and our global development team was strongly committed to the correct CO_2 calculation methods."

Norpe also knows that Alfa Laval has a long reference list concerning challenging refrigeration environments, including supermarkets. "For us as an installer and contractor, it was of great importance to have a reliable and experienced component supplier," states Lasse Silvan, Project Engineer from Norpe. "We also appreciate the quick service in our native language, as well as high technical know-how on the part of Alfa Laval's contact persons."

According to Silvan, the project did not encounter any significant challenges. Supplies came as agreed, and there were no surprises during the pressure and leak tests, which Norpe carried out after installation in November 2012. "

SUMMARY

Lasse Silvan, Project Engineer, Norpe Finland: "Alfa Laval's high commitment to new environmentally friendly cooling solutions is admirable. After many years of close co-operation, I can say that they are honestly interested in customers' needs and are ready to fulfill needs to the smallest detail."

Hannu Viikilä, Segment Manager, Alfa Laval Nordic: "I appreciate Norpe's openness to the new and sustainable solutions we can offer. When operating with such a challenging refrigerant like carbon dioxide, it is rewarding that our partner also wants to see our R&D environment with all of its frills."

WATER SOURCE CO_2 REFRIGERANT HOT WATER HEAT PUMP APPLICATION

ABOUT THE COMPANY

MYCOM Mayekawa is a leading provider of energy efficient compressors and thermal systems. Its focus is on developing energy efficient technology for refrigeration, air conditioning, and heating applications.

Mayekawa emphasizes the use of the "Natural Five" refrigerants (water, air, ammonia, CO_2 and hydrocarbons), which have the greatest application potential for the next generation of thermal applications and solutions.

More information at:
www.mayekawausa.com

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INTRODUCTION

Out of concerns over rising energy costs and the commitment to sustainable operations, Somerston Wine Co., producer of Highflyer, Priest Ranch and Somerston wines installed the first ever integrated CO_2 refrigerant heat pump heating and cooling system implemented in a winery in North America. The installation is at the state of the art, energy efficient winery, located in a renovated 12,000 sq. ft. (1,115 m^2) barn, high in the eastern mountains of Napa Valley, California on Somerston's 1,682 acre (680 ha) ranch. It was designed to be functional, practical, and energy efficient. Somerston's sustainable operations will eventually expand to include a neighboring structure with solar powered lithium batteries, resulting in a winery that is 100% off the grid.

A typical winery would use a natural gas or propane hot water boiler, in addition to an air cooled or water cooled electric chiller for the hot water and chilled glycol systems used for tank fermentation control and barrel room cooling / heating requirements. These separate components cannot recover the heat that is wasted through the air cooled or water cooled condenser of the electric chiller. Futhermore, hot water above 180°F (82°C) is required, which cannot be met using a standard heat pump system.

ABOUT THE SYSTEM

The integrated MYCOM ECO Cute CO_2 refrigerant heat pump heating and cooling system is comprised of four elements: a MYCOM CO_2 refrigerant heat pump, a hybrid adiabatic fluid cooler that replaces the traditional cooling tower, a glycol warming system for tank and barrel room heating, and a high efficiency water cooled glycol chiller for additional tank and barrel room cooling. The components represent cutting-edge technology used only by a handful of companies in the world, and Somerston Wine Co. is the first to integrate the components into a complete system. The CO_2 heat pump system operates with zero emissions, as it is all electric, while also achieving a coefficient of performance vastly higher than traditional propane-based hot water boilers and standard refrigerant heat pumps, which requires high temperature hot water. Where a standard propane-based hot water boiler is 80 percent efficient, Somerston's CO_2 heat pump is 360 to 400 percent efficient while performing heating and cooling functions at the same time.

In addition, Somerston's MYCOM CO_2 refrigerant 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 first component, a MYCOM Eco Cute electric-driven, water source, hot water heat pump, uses CO_2 as a refrigerant for glycol cooling and hot water heating, all in the same unit. It is more efficient than a standard hot water boiler, especially while heating and cooling simultaneously. The heat pump operates using the transcritical refrigeration cycle. By using CO_2 instead of gas fired boilers and HFC refrigerants, Somerston's system results in a 28% lower carbon footprint overall. This MYCOM CO_2 refrigerant heat pump made its North American debut at the Somerston winery; it is backed with a proven record of performance and effectiveness in Japan and Europe. A large insulated hot water storage tank was also installed for winery peak load requirements.

The second component of Somerston's system is a hybrid adiabatic fluid cooler, which replaces the traditional cooling tower. While traditional towers require large amounts of water and have high maintenance costs, Somerston's fluid cooler acts as an air cooler during temperate months and a wet cooler during hotter months. Somerston is the first winery in the USA to utilize this technology.

A larger, high-efficiency electric glycol chiller for harvest cooling loads and a glycol warmer are the final components of the system and are used for tank and barrel room cooling. The MYCOM CO_2 heat pump is used as an integrated component with these other systems to indirectly warm glycol with a special safety plate heat exchanger and directly cool glycol. This results in dramatically lower energy requirements than traditional systems, bringing Somerston's ideals of a sustainable, environmentally conscious property full circle.

> *"Somerston's guiding mission is to operate systemically as a sustainable, efficient, and land-focused project," says Craig Becker, partner, General Manager, winemaker, and vineyard Manager at Somerston Wine Co. "While plenty of producers build efficiently, they rarely operate efficiently. Every element of the Somerston winery has a purpose, and the energy savings for the integrated CO_2 heating and cooling system will pay for the system's additional cost within three years."*

RESULTS

Environmental Impact: Using CO_2 as the refrigerant for the heat pump system allows for high hot water temperatures in addition to eliminating the use of HCFC and HFC refrigerants. A 28% overall reduction in greenhouse gas emissions was also achieved.

Safety: The MYCOM heat pump is a closed type system that has a total CO_2 refrigerant charge of 24 lbs, along with safety interlocks to ensure safe and reliable operation.

Costs: The overall cost of using the hybrid components in an integrated system versus a separate gas boiler and glycol chiller system resulted in a 25% premium. The additional costs are expected to be recovered within three years.

Energy Efficiency: By combining the hot water heating system with the glycol cooling system using the MYCOM heat pump unit, a high COP is realized, unlike when using separate systems. 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 MYCOM 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.

SUMMARY

The use of transcritical heat pumps for high temperature hot water heating is a proven technology with very good overall energy efficiency. In addition, the water source version, as described in this case study, has many applications, including Hotels/ Resorts, Food Processors, Dairies, Breweries, Manufacturing, and even Building HVAC systems that have a high temperature hot water load and simultaneous cooling load. These types of applications can result in maximum energy savings, while using environmentally friendly equipment.

MYCOM
MAYEKAWA

LOW REFRIGERANT CHARGE AMMONIA/CO_2 CHILLER IN A SUPERMARKET APPLICATION

MYCOM MAYEKAWA

ABOUT THE COMPANY

MYCOM Mayekawa is a leading provider of energy efficient compressors and thermal systems. Our focus is on developing energy efficient technology for refrigeration, air conditioning and heating applications.

We emphasize the use of "Natural Five" refrigerants (water, air, ammonia, CO_2 and hydrocarbons) which have the greatest application potential for the next generation of thermal applications and solutions.

More information at:
www.mayekawausa.com

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INTRODUCTION

The phase out of CFC and HCFC refrigerants and the unknown future of their replacement refrigerants have led the supermarket industry to look to alternative, long term, energy efficient solutions. Carbon dioxide (R 744) is rapidly becoming the industry choice for an alternative refrigerant due to its favorable environmental properties (ODP = 0, GWP = 1). Many of these systems are installed using CO_2 as a secondary fluid, circulated through the store to the cases while an HFC refrigerant is still used as the primary refrigerant at the compressor rack.

Another natural choice for refrigerant is ammonia, R717(ODP = 0, GWP = 0). Ammonia has been used since the beginning of mechanical refrigeration due to its efficiency and ease of availability. These applications were typically industrial systems with more than 10,000 lbs of charge. Due to the size of the typical installation, it was not considered as an alternative to synthetic refrigerants in commercial applications. However, new technology in the past ten years has allowed ammonia systems to be designed with significantly lower charges. Low charge systems make it easier to manage the safety of an ammonia system for operators and those who are around the system.

SuperValu approached MYCOM Mayekawa to develop a low charge ammonia/CO_2 chiller that would be part of a CO_2 cascade refrigeration system for an Albertsons test store in Carpinteria, California, which would use 100% natural refrigerants. This collaborative effort would bring the most trusted names in supermarket refrigeration together to show the strength of an all natural refrigerant store, particularly in energy efficiency.

ABOUT THE SYSTEM

MYCOM designed and built the ammonia chiller portion of the refrigeration system for SUPERVALU's Carpinteria store. The MYCOM unit consisted of the compressors, condensers, and CO_2 heat exchanger that supplied liquid CO_2 to the CO_2 refrigerant skid for distribution to the store.

The design approach for the unit was to develop a skid that was bulletproof and could be used to prove the concept of using ammonia in a supermarket application. Easily available industrial components were used for ease of replacement and familiarity to the service base in the area.

The ammonia unit needed to supply the store with a refrigeration capacity of 860 kbtu/hr (~71TR). This was achieved using a MYCOM M Series reciprocating compressor. The M Series is MYCOM's next generation reciprocating compressor, specially designed to be used for natural refrigerants with high efficiency. The compressor is coupled to a 125 HP motor with variable frequency drive. The VFD can match load conditions in the store to make sure the system is always operating most efficiently.

Many energy efficiency design elements were included in the skid to reduce energy consumption. The ammonia system uses a flooded plate/shell heat exchanger to condense the CO_2 vapor returning from the store back to a liquid. The flooded design increases efficiency over a direct expansion system, and the plate/shell heat exchanger allows for a narrow temperature (7°F or -14°C TD) difference to raise the suction temperature (13°F or -10°C SST) on the compressor to save energy.

A key design element of the skid was to keep the charge of the unit low so that the risk of an ammonia release was mitigated by the small amount of ammonia in the system. Unlike federal guidelines for systems over 10,000 lbs of ammonia, the State of California's limit is 500 lbs (227 kg). This makes the amount of ammonia in the system critical. For this unit, even with a flooded design, the charge of the unit during start up was 250 lbs (113 kg).

The safety of the skid was a critical design element since this unit was being placed in a retail location. Ammonia sensors can give early warnings of a release and shut down the compressors to mitigate a release. High powered fans blow the ammonia up and away from the unit in the event of a release. To prevent over pressurization of the unit, pressure can be blown down from high points in the system to the low side. This system attempts to reduce the high pressure points of the system into the low pressure side to prevent the relief valves from lifting. In addition, the base pan of the unit is fully welded to prevent ammonia from spilling onto the roof and into the store in an ammonia loss situation.

RESULTS

Environmental Impact: Using ammonia as a refrigerant eliminates the need for synthetic refrigerants that negatively impact the ozone and have a large green house gas impact. The skid is also designed for energy efficiency and consumes less power than a comparably sized Freon system.

Safety: Safety is a concern whenever ammonia is used due to its strong smell and potential for harm in high concentrations. The low ammonia charge (250 lbs or 113 kg) and integrated safety systems manage this risk. The safety system on the unit has the same safety design elements as units 10 times as large.

Costs: This unit was designed and constructed as a test system to prove the viability of using ammonia in a supermarket environment. This is not a standard production unit, and it contains a number of elements that increase the cost. There is a fully redundant compressor, motor, and VFD. This not only raises the initial cost of the unit but the life cycle cost as well. Future development will focus on standardizing the skid to further reduce costs.

Energy Efficiency: The strength of ammonia refrigerating systems is their energy efficiency. The combination of the flooded heat exchanger, energy efficient compressor, ammonia as a refrigerant, and water cooled condensing show a preliminary energy advantage of over 30%, compared to a conventional Freon type system. This is an incredible leap forward in efficiency and uses a natural refrigerant to achieve it.

SUMMARY

The collaborative effort to bring ammonia to a supermarket setting, spearheaded by SUPERVALU at their Carpinteria Albertsons store, demonstrates that ammonia is an environmentally friendly, energy efficient alterative to synthetic refrigerants. Preliminary energy savings of using an ammonia/CO_2 system are 30% greater than for conventional systems. This represents a significant increase over previous systems.

While there are still concerns over the safety of using ammonia in supermarkets, the energy values are worthy of serious consideration.

ENERGY EFFICIENT HYDROCARBON ICE MACHINES

ABOUT THE COMPANY

Danfoss is a world leader in the research, development, and production of high efficiency electronic and mechanical components and controls for air-conditioning, heating, refrigeration, and motion control systems, as well as for renewable energy technology solutions, such as solar power. Danfoss focuses on combining innovative engineering, energy efficiency, and environmental responsibility. This includes leading the industry in the adoption of natural and lower GWP refrigerants, including ammonia, CO_2, and hydrocarbons.

More information at:
www.danfoss.us

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INTRODUCTION

For the commercial food service and related industries, which rely daily on large quantities of ice for food displays, safety, preparation, beverages, etc., the ability to reliably and cost efficiently produce ice can have an impact on a business' operation. Between 2005 and 2010, Manitowoc Ice, Inc., the Wisconsin-based manufacturer of commercial ice machines, became interested in taking its product portfolio one step further. It turned to Danfoss with the idea of designing an ice machine that would improve customers' sustainability efforts by operating on natural refrigerants.

The collaboration with Danfoss led to the development of two new models within Manitowoc's Indigo Series and two Q-Series under-counter units that are cooled by R290 or propane, which Manitowoc introduced in mid-2011. The use of an environmentally friendly hydrocarbon refrigerant enables Manitowoc to offer customers a product with zero ozone depletion potential (ODP) and low global warming potential (GWP), which also improves energy efficiency and reduces operating costs.

ABOUT THE SYSTEM

Fueled by increasing market interest in environmentally friendly systems and practices, and a goal of preparing the global market for greater hydrocarbon acceptance, the first collaborative project was Manitowoc's 500-pound ice machine. To convert the ice machine to natural refrigerants, Danfoss replaced a compressor using R-404a, a hydrofluorocarbon (HFC), with a new compressor designed for R290, a hydrocarbon (HC).

Knowing it would also help reduce energy use, Danfoss chose to install one of its SC Series compressors (SC18CNX) for R290, which features a reliable, compact design and a motor with specially-optimized valves and internal motor protection. The SC compressor offers high cooling capacities, low noise levels, and low energy consumption at high ambient temperatures (113° F or 235° C). The SC Series from Secop is part of a large product range designed for R290, which will be continuously extended and improved to provide high energy efficient compressors for natural refrigerants. It can serve both the 115 Volt as well as the 230 Volt markets. In early 2013, Secop will introduce four new models for R290 from the TL and the NL series, with 115 Volt supply.

To further improve the efficiency of the ice machines, Manitowoc installed a specially designed Danfoss TU thermostatic expansion valve, which helps to optimize the charge and regulate the injection of the refrigerant. Manitowoc also replaced the condenser with a new Danfoss microchannel condenser.

MANITOWOC R290 PERFORMANCE COMPARISON CHART

Model #	IYP0324A	IY0324A	IY0524A	QYP0274	QY0274
User Inputs					
Condenser Type	Air Cooled	Air Cooled	Air Cooled	Air Cooled	Air Cooled
Refrigerant Type	R290	R404A	R404A	R290	R404A
Ice Harvest Rate @ 90°/70°	235	230	360	235	206
Energy Consumption	5.59	7.32	6.45	6.14	8.64
- % difference	-	23.63%	13%		25%
Potable Water Consumption (100 lbs. of Ice)	23.9	23.9	23.8	32.0	32.0
Ice Machine Usage					
Pounds of Ice Made per Day (lbs/day)	200	200	200	200	200
Operating Days per Year (d/year)	365	365	365	365	365
Utility Cost and Lifespan					
Electric Cost per kWh ($/kWh)	$0.19	$0.19	$0.19	$0.19	$0.19
Water/Sewer Cost per Gallon	$0.007	$0.007	$0.007	$0.007	$0.007
Est. Lifespan of Ice Maker in Years	10	10	10	10	10
Results: Energy Cost					
Annual Energy Cost	$783	$1,015	$895	$852	$1,198
Annual Water Cost per Gallon	$122	$122	$122	$164	$164
Results: Total Cost	IYP0324A	IY0324A	IY0524A	QYP0274	QY0274
Lifetime Water Cost	$122	$122	$122	$164	$164
Lifetime Energy Cost	$783	$1,015	$895	$852	$1,198
Annual Cost Total	$905	$1,137	$1,016	$1,015	$1,362
Annual Cost Savings	$172			$347	

"The decision to offer units operating R290 was primarily driven by some of our large accounts' internal demand to become more environmentally friendly. We are currently looking at other natural refrigerants like CO_2, but R290 provides the great energy efficiency benefits that our customers are also demanding."

- Greg Erickson, Field Marketing Manager at Manitowoc Ice, Inc.

RESULTS & SUMMARY

Production Capacity: Typically, replacing R-404a with natural R290 causes production (the volume of ice harvest within each 24-hour period) losses up to 10%. However, by increasing compressor displacement with R290, reducing operating pressure with microchannel heat exchangers, and optimizing component selection, Danfoss and Manitowoc were able to maintain ice production capacity of the R290 systems at the same level as R404a systems, while staying within the 150g charge limit.

Q-Series QYP-0214A-251	Q-Series QYP-0274A-251	Indigo Series IYP-0324A-251	Indigo Series IYP-0504A-251
26" (66cm) wide (under-counter)	30" (76cm) wide (under-counter)	22" (55cm) wide	30" (76cm) wide
215 lbs. (98kg) ice production in 24 hours	280 lbs. (127kg) ice production in 24 hours	350 lbs. (159 kg) ice production in 24 hours	485 lbs. (220kg) ice production in 24 hours
80 lbs. (36kg) ice storage capacity	100 lbs. (45kg) ice storage capacity	Mounts on storage bins or beverage dispense applications	

Energy Efficiency: Although the introduction of hydrocarbon refrigerants was first and foremost intended to create an environmentally friendly system promoting sustainable practices, the lower pressure ratio and discharge temperatures of R290, combined with the high efficiency compressor and components, work together to save 20 to 30% more energy than comparable ice machines. This is a direct benefit to customers, who are also motivated by a reduction in energy costs over time.

Local & Global Production: To date, the R290 Indigo Series ice machines are being manufactured for and sold to the European market. However, according to Erickson, Manitowoc is producing the R290 Indigo units at the company's facilities in Wisconsin and the Q-Series under-counter units in China.

"Because of its readiness for natural refrigerants, we saw the European market as an opportunity to put a stake in the ground and showcase a proven technology. We believe the R290 ice machines will become much more relevant here in the United States over the coming years – and we'll be prepared with environmentally friendly and energy efficient ice machines when that day comes."

Deploying these technologies in the USA market will, however, first require tackling a few large hurdles, including the modification of safety standards, which the industry hopes will happen in 2013. Only then can the SNAP approval process for R290 ice machines move forward, and only then can these low GWP, energy efficient hydrocarbon refrigeration systems begin to reshape the market and its environmental impact.

Danfoss received Manitowoc's 2011 Technology Supplier of the Year award for their critical role in this project.

TRANSCRITICAL CO_2 BOOSTER SYSTEM IN NORTH AMERICA

ABOUT THE COMPANY

Hill PHOENIX, Inc., a Dover Company, is based in Conyers, GA. The company designs and manufactures commercial refrigerated display cases and specialty products, refrigeration systems, integrated power distribution systems, and walk-in coolers and freezers. Advansor's transcritical CO_2 booster systems are designed and manufactured in the Hillphoenix refrigeration systems facility in Conyers, GA. They are currently building and shipping to supermarkets throughout North America.

More information at:
www.hillphoenix.com

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INTRODUCTION

When Overwaitea Food Group (OFG) chose The Village on False Creek as the location for its newest Urban Fare Express, the bar for sustainability was set high. As a leader in retail sustainability, OFG had already established aggressive goals for green operations in every area of its business, and The Village on False Creek, having earned the highest level of Leadership in Energy and Environmental Design (LEED®) Platinum certification for a neighborhood of its size, was known as one of the most livable and sustainable communities in the world.

OFG is once again setting a benchmark for green retail practices by installing a Hillphoenix Advansor transcritical CO_2 booster refrigeration system in its False Creek store. Urban Fare Express is one of only a handful of HFC (hydrofluorocarbons) - free grocery stores in Canada. This is the first Hillphoenix Advansor transcritical CO_2 booster refrigeration system installed in North America.

OFG began experimenting with CO_2 refrigeration systems in 2010. This followed a long history of commitment to the environment, starting with its first Environmental Stewardship Award nearly 20 years ago.

In addition to its move toward CO_2, many OFG stores feature a variety of smart technologies designed to reduce energy consumption, including:

- High-efficiency lighting with motion sensors in freezer cases
- Energy reduced refrigeration systems
- Energy efficient freezer doors
- High-efficiency, programmable deli and bakery ovens
- Waste-heat recovery systems
- Building automation systems that adjust lighting, heating, and air conditioning as needed

"Recycling, sustainable seafood, reusable bags, energy-efficient stores, and our efforts to be the number one supporter of local products and producers are just some of the ways we show our commitment to sustainability every day."

- Carmen Churcott, Vice-President, OFG

ABOUT THE SYSTEM

Hillphoenix Advansor transcritical CO_2 booster system advantages:

- The Advansor transcritical CO_2 booster system utilizes CO_2 as the only refrigerant covering both medium-temp and low-temp loads.
- CO_2 has a high temperature heat of rejection, making it ideal for hot water heat reclamation applications and efficient hot gas defrosting.
- CO_2 systems operate under much higher pressures than conventional HFC-based systems. Many CO_2 systems require steel piping throughout and carry a higher risk of pressure-related system breakdowns. The Advansor system eliminates those concerns by perfecting the use of pressure reducing valves, so that everything inside of the store operates under lower pressure, as it would with an HFC-based system. Contractors can use copper piping and retailers can rest easy knowing that their Advansor system maintains pressures within a range, normally found in traditional DX systems. OFG's Urban Fare Express has a back-up auxiliary condensing unit on a back-up generator in case of power failure. The smaller condensing unit cools the CO_2 and keeps the pressure low to prevent the loss of CO_2.
- Hillphoenix R&D capabilities ensure that CO_2 technology is a viable option for every merchandising configuration. From walk-ins to custom specialty cases, Advansor technology is available across all Hillphoenix product lines.

Construction of the 23,000 sq. ft. (2137m^2) Urban Fare Express entailed retrofitting a former Olympic Village structure to accommodate a grocery store and all of its associated systems. One particular challenge included putting the gas cooler in the parking deck. Such a configuration had to include special sound attenuating mufflers and ducts to move hot air outside of the garage building.

SUMMARY

HFCs have been the refrigerant of choice in the supermarket industry for decades. However, HFCs are a greenhouse gas and contribute to global warming. Increasingly, food retailers are moving toward more sustainable natural refrigerants including CO_2. It takes 2000-4000 pounds (907-1814 kg) of carbon dioxide to equal the global warming potential of just one pound (0,5 kg) of leaked HFC refrigerant.

> *"We chose a transcritical CO_2 booster system because it's 100 percent HFC-free. We've seen a number of synthetic refrigerants phased out over the years, and with its high global warming potential, we expect that eventually the current HFC's will be phased out, too. CO_2 transitions us to a natural refrigerant that we can live with in the future."*
>
> - Ralph Thiel, Director, Store Planning & Construction for Overwaitea Food Group LP

Aside from the green appeal of CO_2, it's a much cheaper alternative to HFC refrigerants (less than $2 per lb (0,5 kg) compared to $20 per lb (0,5 kg). So why haven't more retailers made the switch? CO_2 systems are still relatively new to supermarket applications. As companies like OFG demonstrate the advantages of CO_2, industry acceptance will no doubt increase.

> *"Our company is dedicated to CO_2 in all new stores in urban settings and any location where there is a population base with enough tradesmen to be trained on CO2 technologies."*
>
> - Ralph Thiel, Director, Store Planning & Construction for Overwaitea Food Group LP

Hillphoenix
A DOVER COMPANY

NATURAL REFRIGERANTS IN NORTH AMERICA TOMORROW

TREND FORECASTS AND EXPECTATIONS

END USER VIEWS ON NATURAL REFRIGERANTS

Leading end-users share their thoughts on how to bring natural refrigerants faster to market, and how they see the natural refrigerant market evolving over the next 5 years on...

PAGE 84

NORTH AMERICAN INDUSTRY SURVEY

Over 550 North American industry experts have voiced their expectations and priorities for the heating, refrigeration, and air conditioning sectors. Find out what their responses were for questions about levels of familiarity with natural refrigerant products; which natural refrigerants will dominate in the future and the potential for North America to become a world leader for HFC-free solutions, on ...

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END-USER VIEWS ON NATURAL REFRIGERANTS

IF YOU HAD TO FORMULATE A GLOBAL ACTION PLAN TO BRING NATURAL REFRIGERANTS FASTER TO MARKET WHAT WOULD YOUR TOP 3 PRIORITIES BE?

I'd form some working groups with technical educators and contracting firms as well as industry experts (retailers and mfrs) and government agencies and NGOs to design an awareness campaign and education curriculum. This process would lay out why there is a need for moving to natural refrigerants, as well as increase the demand for those systems and the corresponding engineering and installation & maintenance contracting services for them. We'd also develop training programs and work with information technology experts to design best control and feedback systems for continuous commissioning, diagnostics and management for on-going business case studies to help influence market transformation. I'd also work to determine how best to develop subsidies or additional ways to make the business case easier until the demand is increased and costs come down.

Kathy Loftus, Whole Foods

1) More data and case studies with actual data.

2) An indication of costs coming down (capital and operating costs).

3) Better training on CO_2 transcritical.

Harrison Horning, Delhaize America

1) I think we need to increase the HC charge that can be used in freezers. That would drive many more opportunities.

2) I think the opportunity of people who are interested in using the technology to collaborate together and to get applications used with greater breadth and depth

3) I would encourage EPA to continue to seek the opportunities to support industry such as ours to really move the technology through the regulatory process to the finishing line.

Andrea Asch, Ben and Jerry's

1) Synergy between government and industry regulating agencies (such EPA/UL) to avoid conflicting approval messages that are received by end users.

2) Regulation in the training of service technicians through either Government or industry organizations to ensure technicians are knowledgeable and qualified to service equipment with natural refrigerants.

3) Participation by the wholesale suppliers of parts and refrigerants. As an end user of stand-alone small freezers, serviced by local very small refrigeration companies, there is no confidence that even if trained that they would have access to the replacement parts and refrigerants for re-charge.

Deb Rose, Blue Bunny

First and foremost increase the reliability of the components on the compressor side. Another thing would be to see other people step up and make a move in favour of natural refrigerants. I am talking about the end users community. We need more interest from the broader end user community - actual buyers of commercial refrigeration systems. It would be nice to see them step up and say: 'We are interested. We think it will make a difference here'.

A third issue will be to develop access to educational services to help everyone involved, engineers as well as technicians. What we at Coca Cola have observed, is that we are having to develop our own training program for servicing and diagnosing issues for systems using natural refrigerants because there is really not much, especially here in the United States. Some of our internal training was actually outside of the United States due to the lack of educational services here.

Steven Cousins, The Coca-Cola Company

1) Assure full compliance with local regulations and internal company standards;

2) Define & evaluate the business case, and if proven to be feasible, then:

3) Define & agree on a rollout plan.

Rene van Gerwen, Unilever

IF YOU HAD TO FORMULATE A GLOBAL ACTION PLAN TO BRING NATURAL REFRIGERANTS FASTER TO MARKET WHAT WOULD YOUR TOP 3 PRIORITIES BE?

Get CO_2 adopted as the in-store working fluid for refrigeration ASAP. The industry may not agree on what the optimum high-side will be for rejecting heat to the outside but it seems clear that CO_2 is the best working fluid to distribute the "cold" around the store. ALL supermarkets can achieve 90% natural refrigeration by replacing the current in-store refrigerants with CO_2. We have many examples of CO_2 Cascaded systems where the synthetic refrigerant charge has been reduced from 300-400 pounds (136-181kg) down to 250-300 pounds (113-136kg) when close coupled to a CO_2 cascade system. Continue to work with NH_3 system providers to make small charge NH_3 commercially feasible. Put pressure on refrigerated case manufactures to develop self-contained propane options for entire offering.

Richard T. Heath, Supervalu

HOW DO YOU SEE THE MARKET FOR NATURAL REFRIGERANTS EVOLVING OVER THE NEXT 5 YEARS?

I see it evolving a bit slowly over the next year or two but with enhanced communication strategy, training and case studies/lessons learned, the market will more quickly develop in years 3-5.

Kathy Loftus, Whole Foods

We see CO_2 transcritical gradually gaining popularity in the USA as system performance improves and costs come down. More suppliers will enter the market with new and different system features. CO_2 transcritical will be the system of choice globally in cold climates, and will gradually become cost-effective in warmer climates.

Harrison Horning, Delhaize America

Global climate change is happening, it is real, it is an area that is going to impact all of us and refrigerants are a huge contributor to climate change. So it is really one of those unnoticed opportunities that many consumers do not understand in terms of its significance as a source of greenhouse gas emission sources. And I think it is becoming incumbent upon industry to take a leadership role, and that is what we are doing.

Andrea Asch, Ben and Jerry's

Unless the suppliers of home refrigeration systems in the US become involved in the promotion of natural refrigerants, it will be difficult for food manufacturer's, who use small stand-alone refrigerators/freezers for marketing purposes, to influence the quick move to natural refrigerants. If the manufacturers of the home refrigeration sector would leap forward to natural refrigerants, then those shared service technicians and parts supply houses would be encouraged to participate. Once we have their participation, then the US market could quickly adapt as the European markets already have tested and are knowledgeable in the use of the natural refrigerants.

Deb Rose, Blue Bunny

We see the market developing well. Unilever is fully committed to the roll out of natural refrigerants across its global business, and with the board of the Global Consumer Goods Forum also committing to begin phasing out HFCs by 2015, we are confident that a shift to natural refrigerants will only accelerate with time.

Rene van Gerwen, Unilever

WHOLE FOODS HAS CHOSEN TO INVEST IN NATURAL REFRIGERANTS BECAUSE...

They are a sustainable option for refrigeration…both economically and environmentally, which truly is key for future adoption. They address and help mitigate ozone depletion and global warming, and we're always looking at ways to protect and renew our communities and environment.

Kathy Loftus, Whole Foods

THE DELHAIZE GROUP HAS CHOSEN TO INVEST IN NATURAL REFRIGERANTS BECAUSE…

We are committed to reducing our greenhouse gas emissions.

Harrison Horning, Delhaize America

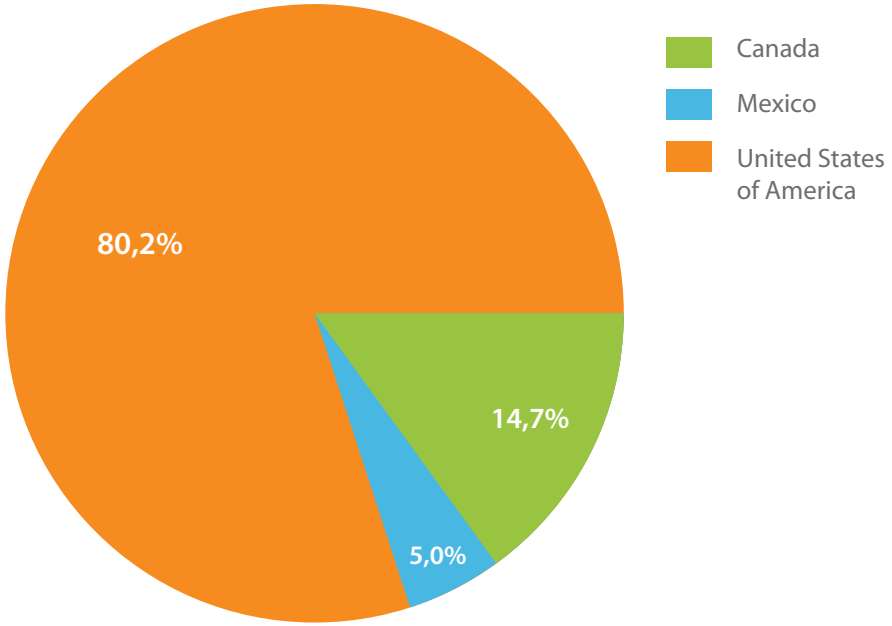
UNILEVER HAS CHOSEN TO INVEST IN NATURAL REFRIGERANTS BECAUSE...

We believe that HC refrigerants for our ice cream freezer cabinets are the best refrigerant option, as this option reduces both direct as well as indirect impact to the environment, while having a sound business case.

Rene van Gerwen, Unilever

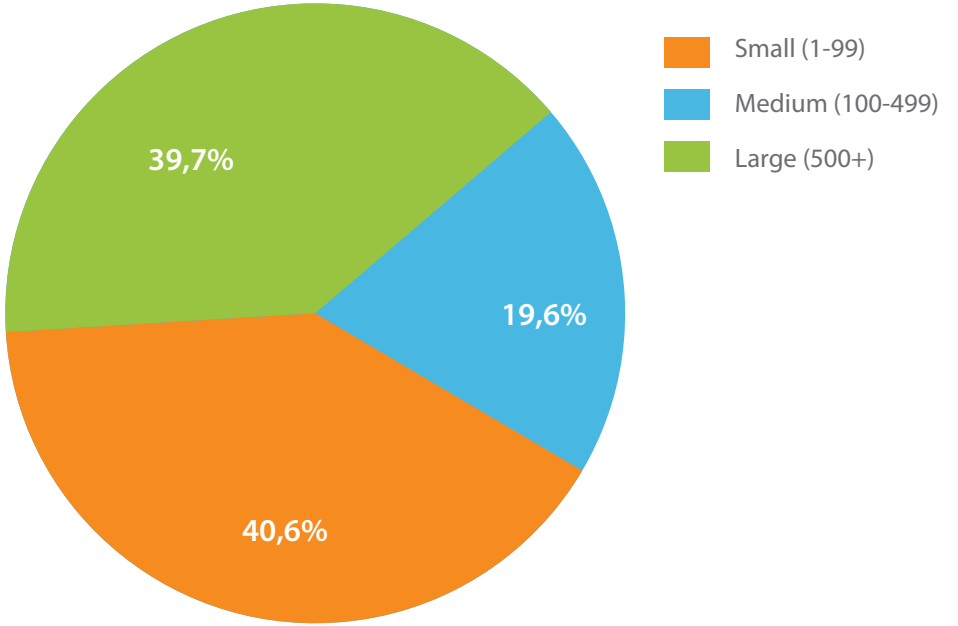
NORTH AMERICAN INDUSTRY SURVEY

RESPONDENTS' PROFILE



ORGANIZATION LOCATION

A large majority of the 556 respondents were based in the United States of America (80%), followed by Canada (15%) and Mexico (5%).



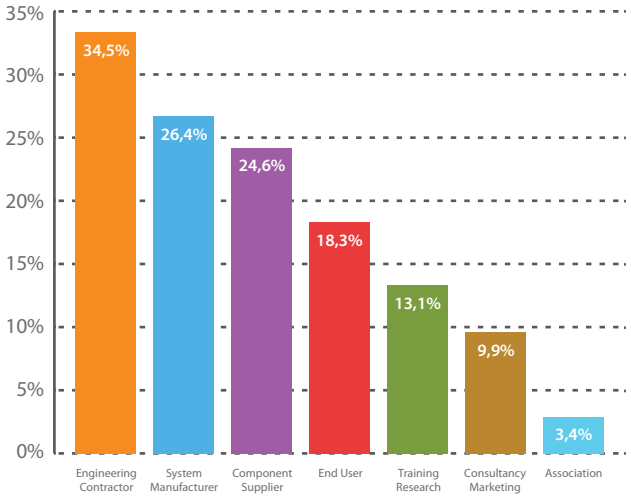
ORGANIZATION SIZE

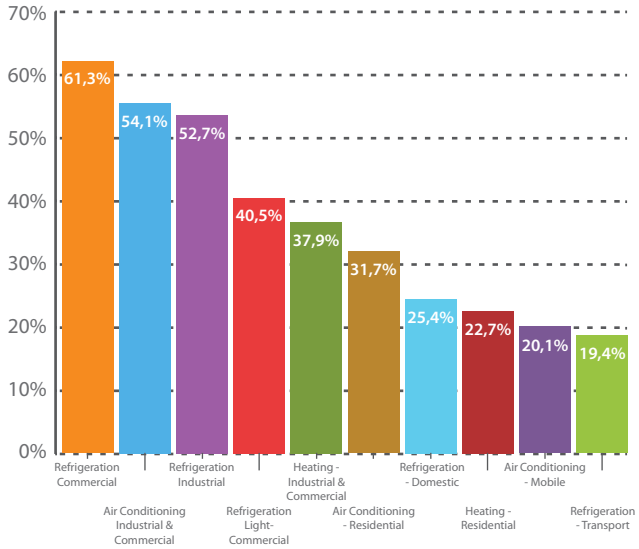
The survey attracted an equal share of respondents representing small organizations with less than 100 staff members (40%), and large organizations with more than 500 employees (40%). Medium-sized organizations were represented to a minor extent (20%).

Total responses: 556

NORTH AMERICAN INDUSTRY SURVEY

RESPONDENTS' PROFILE





ORGANIZATION TYPES

More than one third of HVAC&R respondents represent the engineering / contracting sector (35%), followed by system manufacturers (26%), and component suppliers (25%). Associations and marketing consultancies are significantly less represented with values below 10%. End-users make up close to one fifth of responses (18%), whereas training & research activities are carried out by 13% of respondents. Multiple responses were possible.

ACTIVITIES / INDUSTRY SECTOR

The largest share of respondents (61%) is active in the commercial refrigeration sector, followed by the industrial & commercial air-conditioning business (54%), and by industrial refrigeration (53%). Less pronounced are activities in the light-commercial refrigeration sector. Mobile air conditioning (20%) and transport refrigeration (19%) attracted the lowest share of respondents – industry sectors where the adoption of natural refrigerants has not been as pronounced as in other areas. Multiple responses were possible.

Total responses: 556

NORTH AMERICAN INDUSTRY SURVEY ON NATURAL REFRIGERANTS

To quantify the market for the natural refrigerants ammonia (NH_3), carbon dioxide (CO_2), hydrocarbons (HCs), water (H_2O), and air, an online survey was sent to more than 7,000 HVAC&R professionals and relevant industry associations world-wide. The survey ran from March 6 to November 6 2012. In total, 559 responses were included in the analysis. Specific objectives of the survey were to identify expectations and priorities for the heating, refrigeration, and air-conditioning industry in North America, familiarity levels with natural refrigerants (NR), availability of NR solutions and future plans, and the potential of North America to become a world leader in natural refrigerant solutions. Moreover the survey asked about the general HVAC&R market conditions for NRs, the impact of policy on market development, key purchasing criteria for commercial end-users, and the strengths and weaknesses of NRs compared to traditional solutions.

METHODOLOGY

Although a global industry survey had been conducted in 2011, this new survey was the first to specifically receive only input from industry stakeholders active in Canada, Mexico, and the United States of America. The survey consisted of a mixture of up to 28 structured (closed-ended) and unstructured (open-ended) questions, depending on the question logic selected. Responses were received mainly from a list of 7,000 HVAC&R industry experts from around the world, and various industry associations and voluntary initiatives, such as the GreenChill Program in the US, provided help in disseminating the survey.

As the survey naturally attracted respondents who were familiar with and/or interested in natural refrigerant (NR) technology solutions, there was a clear overrepresentation of the "pro-NR" industry (actors who already offer or use NR systems). To avoid this bias as much as possible, wherever marked differences in response patterns from the total data set could be identified, both sub-sets of "pro-NR" and "non-NR" were explicitly stated and contrasted.

MOST INTEREST FROM USA

As previously stated the large majority of the 556 respondents were located in the United States of America (80%), followed by Canada (15%) and Mexico (5%). Most organizations represented belonged to either a small organization with less than 100 staff members (40%) or a large organization with more than 500 employees (40%). Medium-sized organizations were represented to a minor extent (20%). While the US represented between 84% and 89% of medium to large size companies, relatively more responses were received from smaller organizations in Canada (22%), where the USA only had a share of 70%.

ENGINEERING & CONTRACTING SECTOR DOMINANT

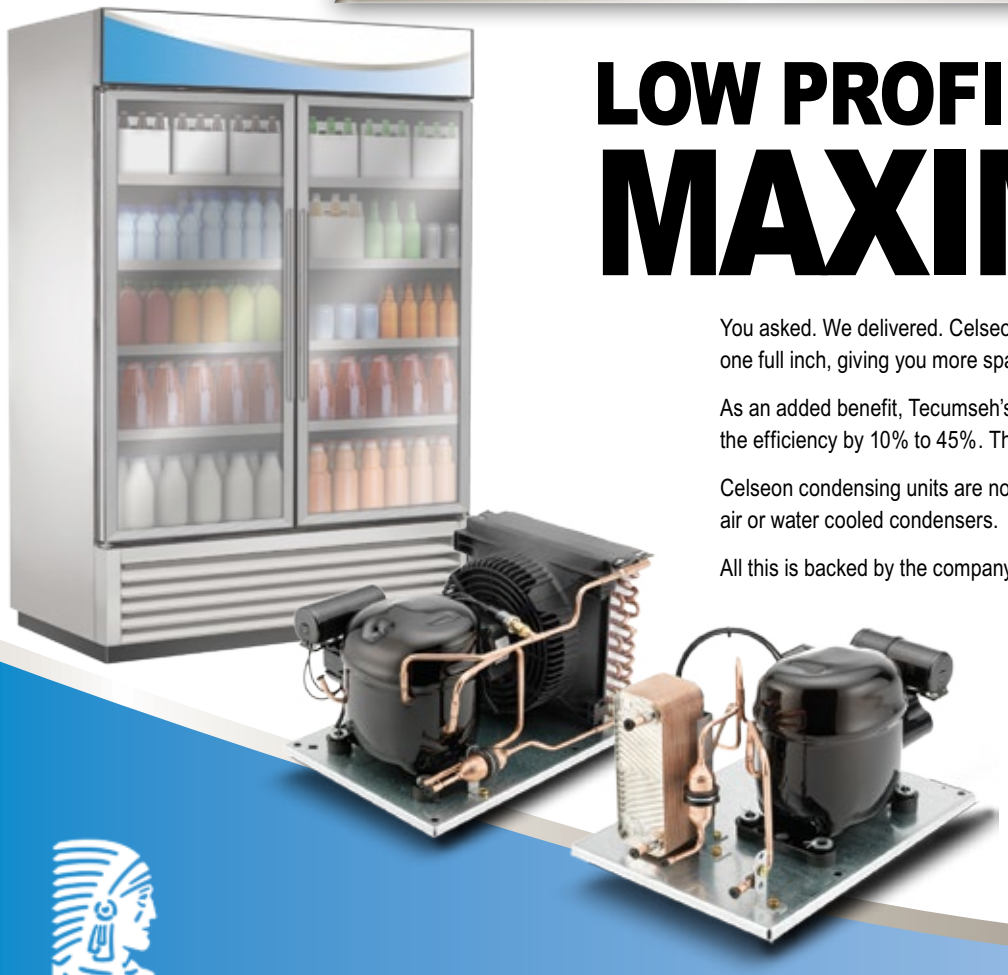
Respondents were first asked to indicate which types of activities their organization is active in; multiple choices were possible. More than one third of participants represented the engineering & contracting sector (35%), followed by a quarter from the system manufacturing business (26%), and component supplying sector (25%). Associations and marketing consultancies were significantly less represented, with values of 3% and 10% respectively. End-users made up close to one fifth of respondents (18%), whereas training & research activities were carried out by 13% of respondents. A cross-tab analysis with the organization size indicated that associations, training & research, as well as consultancy & marketing were evenly distributed, accounting for the whole range of small to large organizations. On the other hand, end-users were mainly found in the "large" category, and both system manufacturers and component suppliers tended to be in the medium to large category. Only Engineering & Contracting – the strongest response group overall – was mainly represented by small companies (50% of which were in this category).

COMMERCIAL REFRIGERATION LARGEST RESPONSE GROUP

The largest share of respondents (61%) was "currently active" – either on the supply or demand side - in the commercial refrigeration sector. More than half of all respondents were (sometimes also) active in the industrial & commercial air-conditioning business (54%) and in industrial refrigeration (53%). This high response rate from the commercial and industrial refrigeration business was to be expected, given the extended use of ammonia in industrial plants and the renewed interest in natural working fluids in supermarket applications.

Slightly less pronounced were activities in the light-commercial refrigeration sector. Mobile air conditioning (20%) and transport refrigeration (19%) attracted the lowest response rate. This was not surprising, given that these industry sectors have adopted natural refrigerants only to a minor extent. The industrial, commercial, and residential heating sectors, as well as the domestic refrigeration and residential air-conditioning sectors, ranged from a 23% to 38% response rate. Again, respondents could select multiple options.

NOW AVAILABLE IN R290



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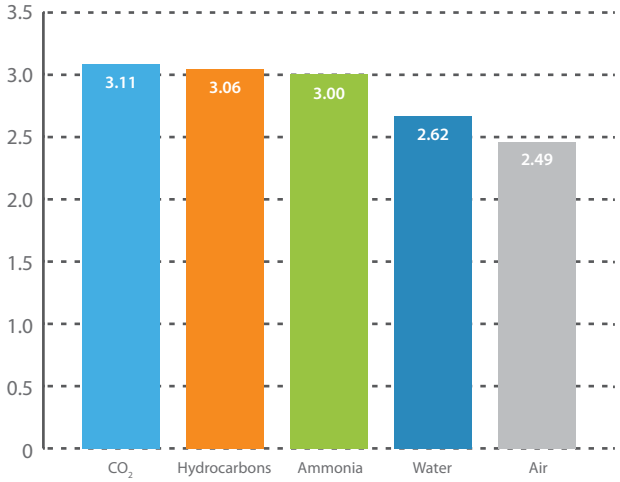
Cooling for a Better Tomorrow™

CELSEON

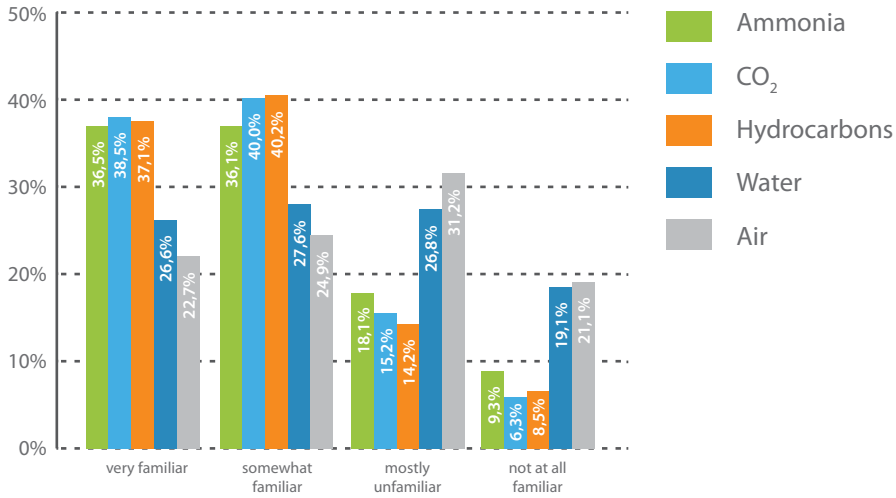
FAMILIARITY WITH NATURAL REFRIGERANTS

QUESTION: How familiar are you with different Natural Refrigerants?

… average values, by refrigerant



…by level of familiarity



MEDIUM LEVEL OF FAMILIARY WITH CO_2, HYDROCARBONS, & AMMONIA…

The refrigerant carbon dioxide was on average, the most well-known natural working fluid. However, with an average value of 3.1 out of a maximum of 4, which indicated "very familiar", there is still room for improvement. Surprisingly, although hydrocarbon refrigerants have only recently been approved for use in small applications in the US, respondents were nearly as familiar with their characteristics as they were with those of CO_2. Ammonia reached similarly high values (3.0 out of 4.0), whereas water and air, in their use as refrigerants, showed a clear information deficit, ranging more in the "mostly unfamiliar" to "somewhat familiar" categories.

… WHILE MORE INFORMATION IS NEEDED ABOUT WATER AND AIR

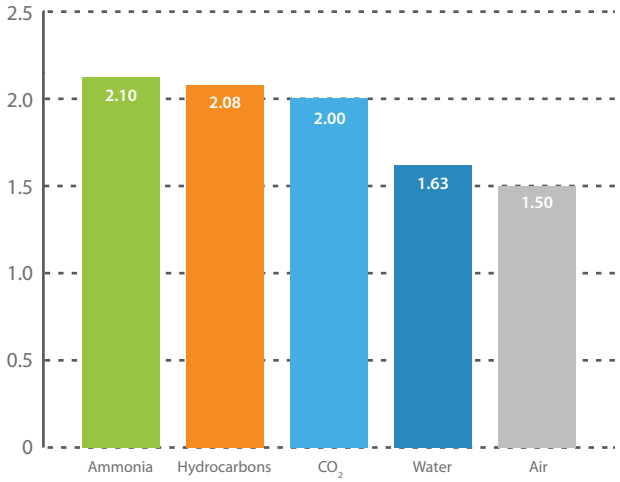
Results shown by level of familiarity indicate that while respondents are either "very familiar" or at least "somewhat familiar" with the use of CO_2, hydrocarbons, and ammonia. The refrigerants air and water would need more support to reach such awareness levels. A significant 52% and 46% of respondents said that they were either "mostly unfamiliar" or "not at all familiar" with air and water, respectively, as refrigerants. A clear knowledge gap exists, and it will need to be closed before a wider market adoption can occur.

Total responses: 493

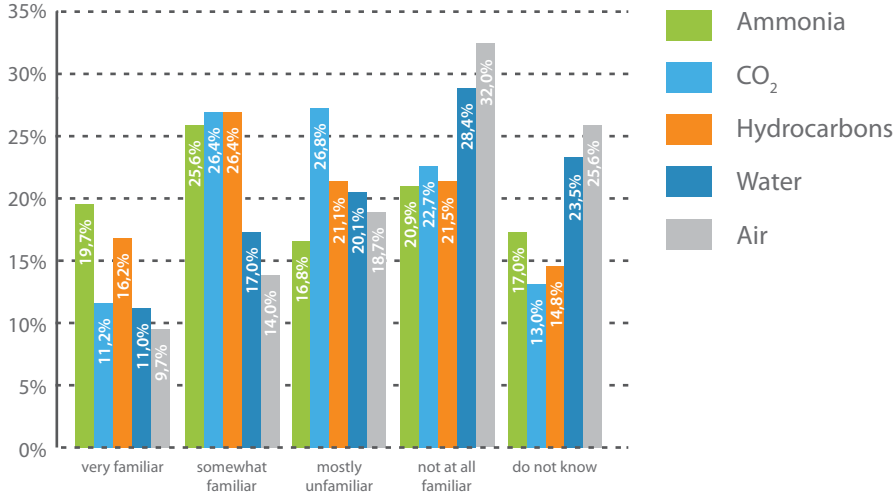
FAMILIARITY WITH NATURAL REFRIGERANTS

QUESTION: How familiar are your customers with Natural Refrigerants?

… average values, by refrigerant



…by level of familiarity



Total responses: 493

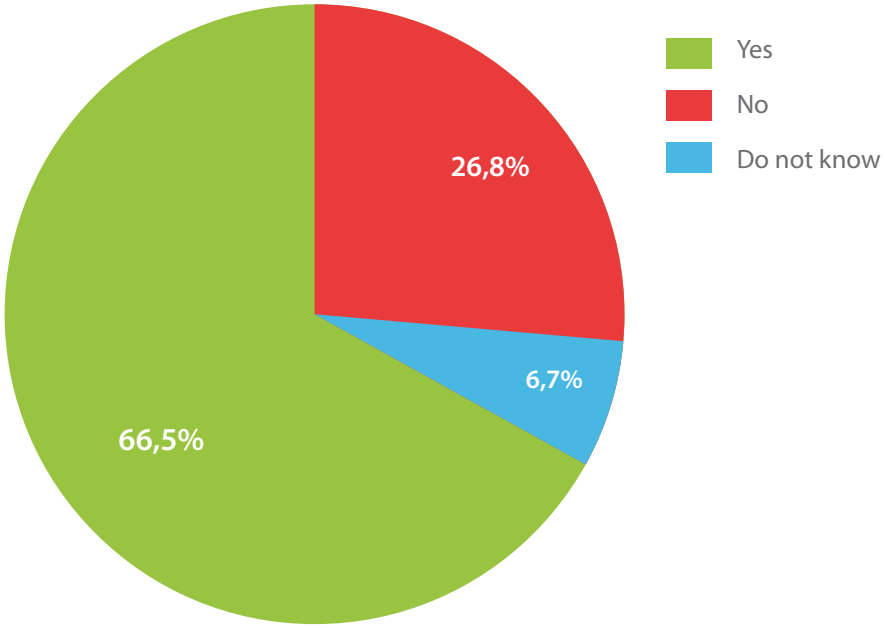
BELOW-AVERAGE FAMILIARITY LEVELS AMONG CUSTOMERS

Compared to the familiarity levels of respondents, their customers seem, to a larger extent, unaware of the use and characteristics of natural refrigerants. Looking at the results per familiarity level, the highest absolute number of respondents thought that their customers' awareness levels were at "somewhat familiar" for ammonia and hydrocarbons, and "mostly unfamiliar" for CO_2. Ammonia the best-rated refrigerant, reached an average familiarity level of 2.1 out of 4.0, indicating that even with this widely used working fluid, customers are, on average, "mostly unfamiliar".

Ammonia clearly enjoyed the highest single familiarity ("very familiar" option) among customers, a result of its continued use in North America. For hydrocarbons, which are expected to enter the North American market rapidly, awareness levels among customers tended to be in the medium range, with 22% of respondents saying that customers are "not at all familiar" with their use. CO_2 ranked mostly in the "somewhat familiar" to "mostly unfamiliar" range. Also interesting was the high selection of the "do not know" option, especially for water and air refrigerants, indicating that respondents were not aware of the refrigerant knowledge of their customers.

NATURAL REFRIGERANT PRODUCTS TODAY & TOMORROW

QUESTION: Do you provide or use any products/ services for Natural Refrigerants?

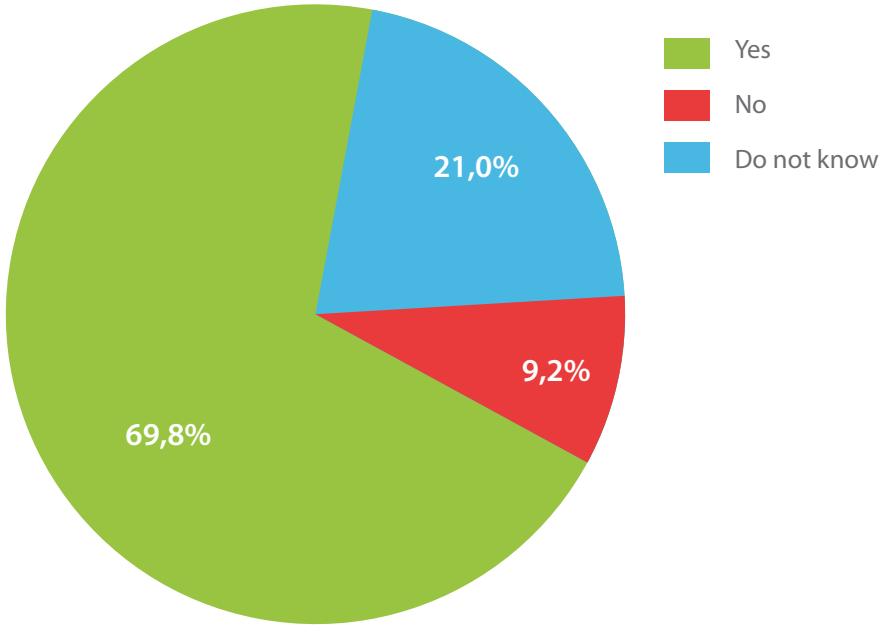


Total responses: 493

67% OF RESPONDENTS USE NATURAL REFRIGERANTS

To this question, 328 out of 493 participants responded that they were already using or providing products and/ or services with natural refrigerants. 7% did not know if the organization they were active in already had activities related to natural working fluids. 27% did not use ammonia, carbon dioxide, hydrocarbons, water, and/ or air in their activities.

QUESTION: Do you plan to provide or use any products / services for Natural Refrigerants?



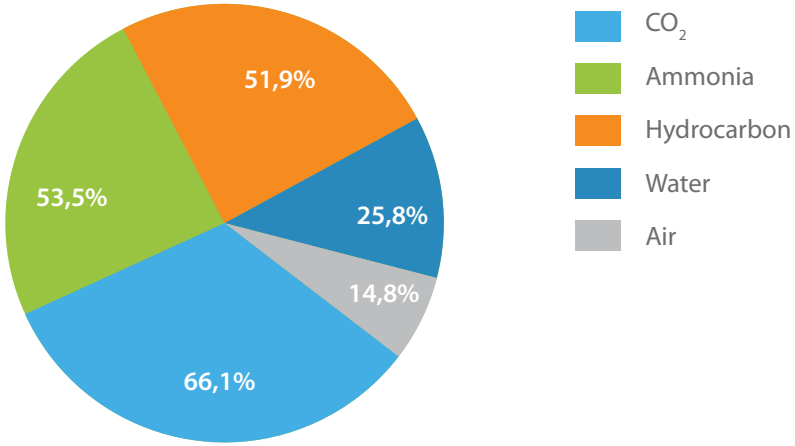
Total responses: 467

70% WILL USE NATURAL REFRIGERANTS IN THE FUTURE

326 respondents were confident that their organization would provide or use natural refrigerants in the future. Only 9% were sure that this would not be the case. A rather high 21% did not clearly know about the plans of the organization they represented. If only looking at the sub-set of respondents who did not currently offer or use NRs (162 individuals), 40% said they were sure they would use NRs in the future, and another 43% opted for "do not know."

NATURAL REFRIGERANTS IN TODAY'S BUSINESS

QUESTION: Which Natural Refrigerants are you using?

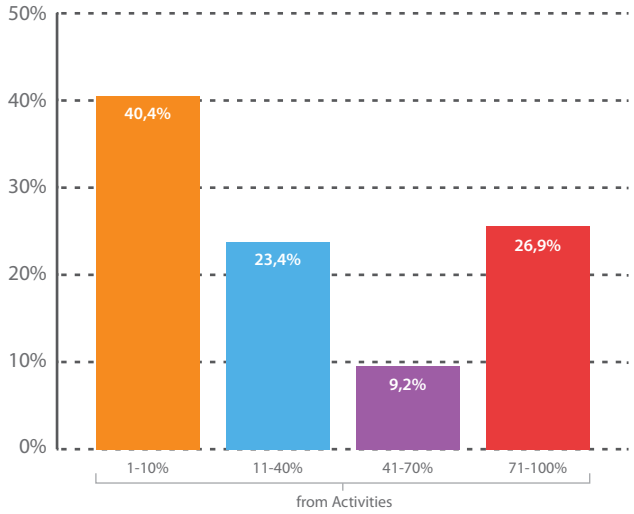


CO_2 MOST WIDELY USED NR IN PRODUCTS & SERVICES OF RESPONDENTS

Total responses: 310

Among the respondents who already provided or used natural refrigerants, 66% used carbon dioxide in their products and/or services, followed by 54% who used ammonia, and 52% who used hydrocarbons. As multiple responses were possible, overlaps for corporations offering / using various natural refrigerants were accounted for. Water (26%) and air (15%) were represented to a minor extent among respondents.

QUESTION: What is the estimated percentage of activities connected to Natural Refrigerants in your organization?



A GROWING BUSINESS CASE FOR NATURAL REFRIGERANTS

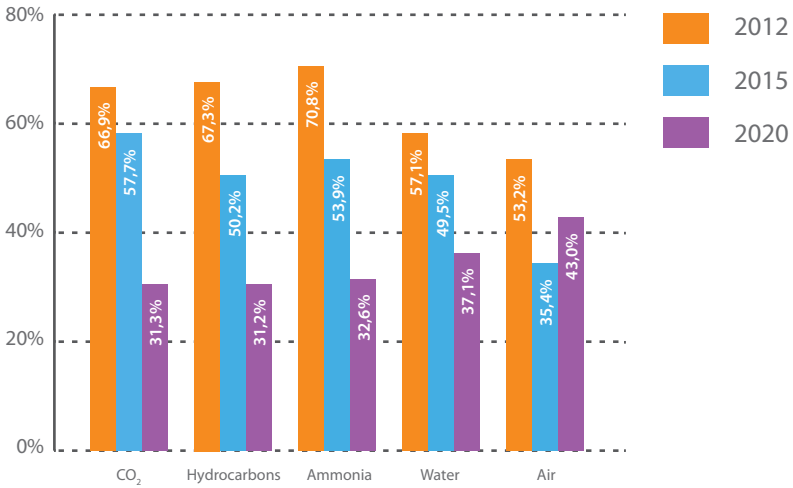
Total responses: 282

Free-text answers about the share of NR-connected activities from the overall activities ranged from "below 1%" to "100%." Most respondents indicated the NR share would be at "10%" (43 responses), followed by "5%" (36 responses), and "90%" (22 responses). Nearly two-thirds (64%) of responses fell in the range of less than 50% NR share. 54 respondents indicated that the NR share would be 90%+, out of which 17 respondents used 100% natural refrigerants. The average across all respondents was at 38% share of natural refrigerant-connected activities. Four groups can be distinguished: starting / lagging behind, growing (late majority), catching-up (early majority), early adopters those leading.

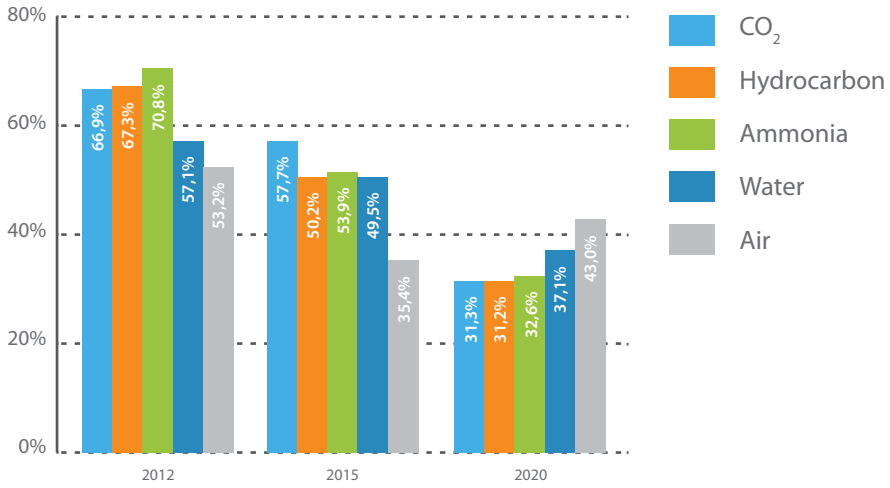
NATURAL REFRIGERANTS TOMORROW

QUESTION: Which Natural Refrigerants are you planning to use, and when?

… by refrigerant



…by year



AMMONIA LEADS IN 2012…

Respondents could indicate which refrigerants they were planning to use by which year, with multiple options possible. For the year 2012, most respondents used ammonia (71%), followed closely by hydrocarbons (67%) and CO_2 (67%). All values, with the exception of air, decreased for the years 2015 and 2020, indicating that respondents were either opting for NR solutions to be introduced immediately, or still hesitating about decisions in the years to come.

…WHILE WATER AND AIR WILL TAKE LARGER SHARES BY 2020

Interestingly, respondents saw the potential of air as a refrigerant first declining in 2015 and then growing again. 37% believed that in 2020, water as a refrigerant would be used, and 43% believed air refrigerant would be used, significantly more than for ammonia, hydrocarbons, and CO_2.

Total responses: 312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THE USE OF NATURAL REFRIGERANTS TODAY & TOMORROW

FAMILIARITY WITH NATURAL REFRIGERANTS

When asked how familiar they themselves were with the use and characteristics of the five natural refrigerants, most respondents indicated that the refrigerant carbon dioxide was, on average, the most well-known natural working fluid. However, with an average value of 3.1 out of a maximum of 4, there was still an awareness gap regarding the "very familiar" option. Surprisingly, and although hydrocarbon refrigerants have only been recently approved, for use in small applications, in the US, respondents were nearly as familiar with their characteristics as those of CO_2. This can be interpreted as a good starting base for a more rapid introduction of hydrocarbons in the US Ammonia reached similar values (3.0 out of 4.0), whereas water (2.6) and air (2.5) ranged in the "somewhat familiar" to "mostly unfamiliar" categories.

Looking at the individual choices of all respondents, the refrigerants air and water would need more support to reach acceptable awareness levels. With 52% and 46% of respondents, saying that they were either "mostly unfamiliar" or "not at all familiar" with air and water refrigerants respectively, a clear knowledge gap exists. This gap will need to be closed before a wider market adoption can occur.

Concerning end-users only (91 responses), familiarity ratings for all individual NRs were consistently lower than for the total response set. Interestingly, hydrocarbons achieved the highest overall awareness level among commercial/industrial end-users (3.0), followed by ammonia (2.9) and CO_2 (2.8). Air received a very modest 2.4 average rating.

For the second related question, all respondents were asked to evaluate the awareness levels of their customers. Most striking was a clear drop in average awareness of customers, compared to respondents' own knowledge. Most respondents thought that their customers' awareness levels were only at a "mostly unfamiliar" level for ammonia (2.1 out of 4.0), hydrocarbons (2.1), and carbon dioxide (2.0). Air and water performed even worse, with average ratings of "not at all familiar" and "mostly unfamiliar", respectively. While ammonia clearly enjoyed the highest level of familiarity ("very familiar" option) among customers, a result of its continued use in North America, the awareness level of hydrocarbons, which are expected to enter the US market rapidly, was in the medium range. 22% of respondents even said that customers were "not at all familiar" with hydrocarbons' use. Also interesting was the high selection of the "do not know" option, especially for water and air refrigerants, indicating that respondents were not aware of the refrigerant knowledge of their customers.

USE OF NATURAL REFRIGERANTS TODAY & TOMORROW

Two-thirds of all survey respondents stated that they already offered or used natural refrigerants. The remaining 27% was split between not currently using or not currently supplying NR technology. 7% of respondents did not know if the organization they represented had any activities involving NR.

Among all respondents, the share that was confident that NRs would be used in the future increased by 4%, reaching 70%, whereas the percentage of individuals clearly saying "no" to NR use in the future decreased by 18%, settling at 9%. The share of "do not know" responses significantly increased. Every fifth respondent was not sure what the organization's future business strategy regarding natural refrigerant solutions would be, suggesting a highly dynamic development over the coming years.

If only considering the sub-set of respondents (162 individuals) that did not currently offer or use NRs, 40% said they were sure to use NRs in the future, and another 43% opted for "do not know". Whereas the first is a strong indication of the future uptake of NRs by new market players, the latter suggests there is room for more activities to promote the benefits of NRs among the currently undecided. Only 17% were sure that they would not use natural working fluids in the future.

Among the sub-group of end-users (91 responses), mostly active in the industrial / commercial air-conditioning, commercial refrigeration, and industrial / commercial heating sectors, 53% already used natural refrigerants, and 54% thought they would use them in the future.

THE BUSINESS CASE FOR NATURAL REFRIGERANTS

In an open-ended question, respondents were asked what the percentage of natural refrigerant-related activities in their organization was. A total of 284 individual answers were received. Responses ranged from "below 1% of our activities" to "100% of our activities". The highest individual answer (the statistical mode) was recorded for "10%" (43 responses), followed by "5%" (36 responses), and "90%" (22 responses), indicating the wide range of stakeholders taking the survey. However, a general observance was that nearly two-thirds (64%) of responses fell in the range of less than 50% NR share. 54 respondents indicated an NR share above 90%, out of which 17 respondents used 100% natural refrigerants in

their business activities. When calculating the arithmetic mean across all responses, a share of 38% of natural refrigerant-connected activities among all respondents is reached. Based on the results, four (unequal) groups can be distinguished: 1) those having either only recently started NR activities or those still lagging behind after lack of investment in NR 2) those growing their NR business, also called the "late majority" in product adoption cycles. 3) those catching up with the leaders, or the "early majority" and 4) the leaders in NR adoption. Group 1 accounts for 40% of respondents, with a 1-10% NR share in business activities; Group 2 accounts for 23%, using 11-40% of NR; Group 3 comprises 9% of respondents, using 41-70% of NR; and Group 4 is made up of 27% of respondents with a dominant share of natural refrigerants of 71-100%.

TYPE OF REFRIGERANTS USED NOW & IN THE FUTURE

Among the respondents already providing or using natural refrigerants, 66% used carbon dioxide in their products and/or services, followed by 54% who used ammonia, and 52% who used hydrocarbons. As multiple responses were possible, overlaps for corporations offering / using various natural refrigerants were accounted for. Water (26%) and air (15%) were represented to a minor extent among respondents.

For the sub-group of end-users (91 responses), the distribution was different from the total response set. Two-thirds (67%) said they use ammonia today, a reflection of the high representation of end-users from the industrial refrigeration and air-conditioning sector in the survey. 58% used carbon dioxide, one third (33%) hydrocarbons, 28% water, and 14% air refrigerant.

The second related question investigated which refrigerants respondents would use in which year. Responses were intended to reflect industry trends and provide an indication of how fast change would happen inside the HVAC&R industry and among end-users. The question looked at all five natural working fluids to investigate the development trends for water and air, which currently show lower application rates than the remaining three groups. Logically, results only reflected responses from those that indicated the intention to use NRs in the future. Hence, the total response set was reduced to 312 individuals. Multiple options were possible per refrigerant, meaning that respondents could indicate if they would use a certain NR in 2012, 2015, and/or 2020. For the year 2012, most respondents used ammonia (71%), followed closely by hydrocarbons (67%) and CO_2 (67%). All values, with the exception of air, decreased in the years 2015 and 2020, indicating that respondents either thought NR solutions would be adopted immediately (in 2012), or that they were still hesitating about decisions for the years to come. Noteworthy is that, respondents saw the potential of air as a refrigerant first declining from 2012 to 2015, and then growing again. 37% believed that in 2020, water would be used as a refrigerant, and 43% believed the same for air refrigerant, a significantly higher percentage than for ammonia, hydrocarbons and CO_2.

BUSINESS & POLICY CLIMATE FOR NR

When asked how the business & policy climate in their country of location would develop for individual natural refrigerants, 78% of respondents indicated that, on average, the conditions for natural refrigerants overall would be either "very favorable" or "rather favorable." Across all natural refrigerants, respondents felt developments were "rather favorable" (2.96).

With a value of 2.99 out of 4.0, the current business & policy climate seems to be the most positive for the refrigerant CO_2. 78% of respondents thought the business & policy climate for CO_2 was either "very favorable" or "rather favorable," compared to 63% for ammonia, and 52% for hydrocarbons. It must be noted that for hydrocarbon refrigerants, the "rather negative" option was the most pronounced (40% of all responses), supporting the assumption that unsolved issues regarding uniform standards and limited application potential due to unsolved legislative approval are affecting the HC industry. Taking into account the "very negative" option for hydrocarbons, nearly half of all respondents (48%) thought the current situation was unsatisfactory.

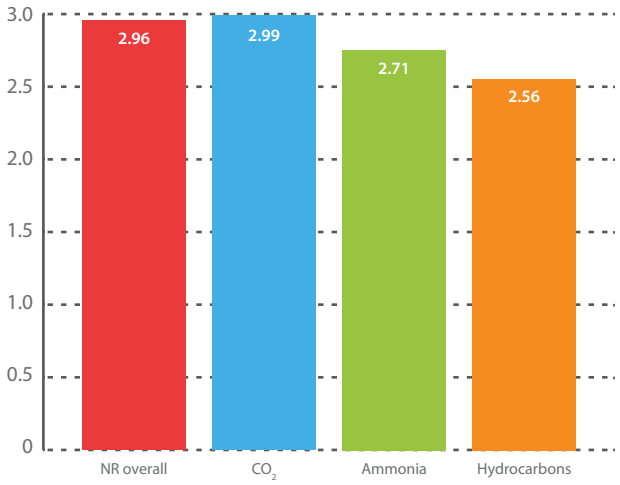
In the sub-group of respondents not using NR today (148 responses), fewer participants believed that developments were positive. For NRs generally, 65% nevertheless believed the situation was "very favorable" or "rather favorable" (average rating: 2.8), while 64% believed the same was true for CO_2 (average rating: 2.8). Among this response group the situation for hydrocarbons was rated to be better than that for ammonia, with 55% saying conditions were beneficial for hydrocarbons (average rating: 2.6), while only 49% said the same about ammonia (average rating: 2.5).

It needs to be noted that refrigerants air and water were not included as individual choices, but it can be assumed that the category "Natural Refrigerants Overall" contained evaluations regarding these two groups.

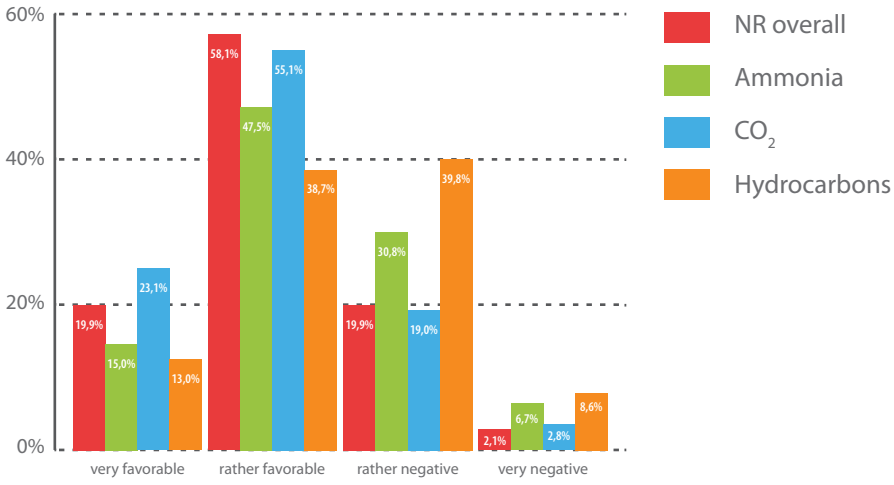
BUSINESS & POLICY CLIMATE

QUESTION: How is the Business & Policy Climate evolving in your country for the following refrigerants:

… average values, by refrigerant



…individual choices, by business & policy climate



78% SEE FAVORABLE BUSINESS CLIMATE FOR NATURAL REFRIGERANTS

With a value of 2.99 out of 4.0, the current business & policy climate seemed to be most positive for the refrigerant CO_2. Across all natural refrigerants, respondents felt developments were "rather favorable" (2.96). Most individual responses fall into the "rather favorable" category. Only for the group of hydrocarbon refrigerants was the "rather negative" option selected the most often (40% of all responses), supporting the assumption that unsolved issues regarding uniform standards and limited application potential were affecting the HC industry.

48% THINK CURRENT CONDITIONS FOR HYDROCARBONS ARE DETRIMENTAL

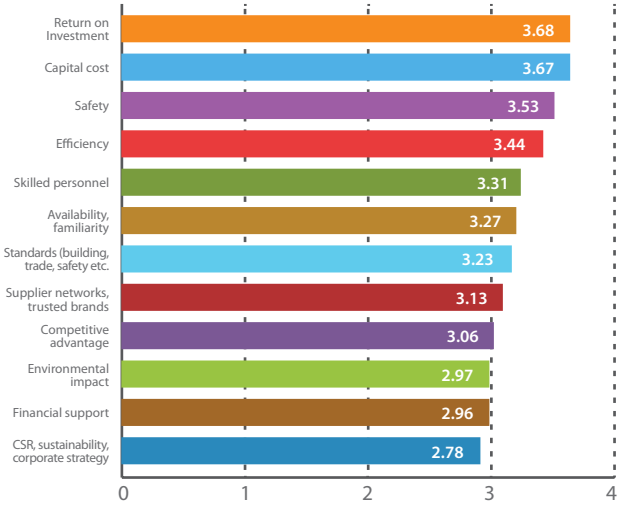
For the individual responses per category, 78% of respondents thought the business & policy climate for CO_2 was either "very favorable" or "rather favorable", compared to 63% for ammonia, and 52% for hydrocarbons. At the other end of the spectrum, the agreement of respondents with the "rather negative" or "very negative" option was especially high for hydrocarbons, with 48% thinking that the current situation was unsatisfactory. Among "Non-NR" respondents, fewer believed that conditions were favorable. In fact, 65% of those not using NR believed that situation was "very favorable" or "rather favorable" (average rating: 2.8).

Total responses: 432

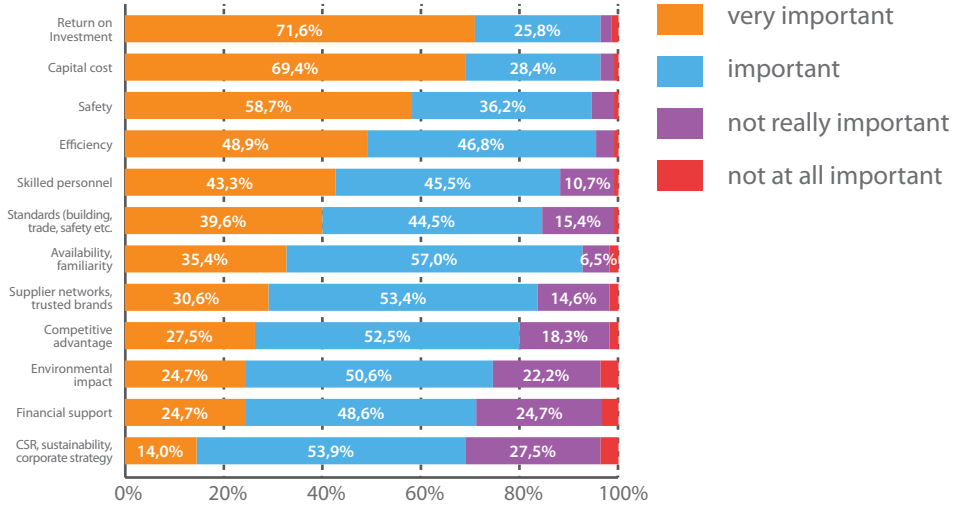
PURCHASING CRITERIA FOR HVAC&R TECHNOLOGY

QUESTION: How important are the following Purchasing Criteria for commercial / industrial end-users in investing in HVAC&R technology?

… average values



…individual choices



Total responses: 356

COSTS, SAFETY & EFFICIENCY THE MOST IMPORTANT PURCHASING CRITERIA

With values of above 3.6 out of 4.0, return on investment and initial investment costs remained "very important" purchasing criteria for commercial end-users, followed closely by safety and efficiency aspects. With values below 3.0, sustainability commitments, available financial support from official sources, and the technology's environmental impact were less important and could be found at the lower end of the priority ranking. In between the two, available know-how and trained personnel were ranked as "important", as well as reliable supply and familiarity with the technology, and the influence of standards in the area of safety, trade, and building codes.

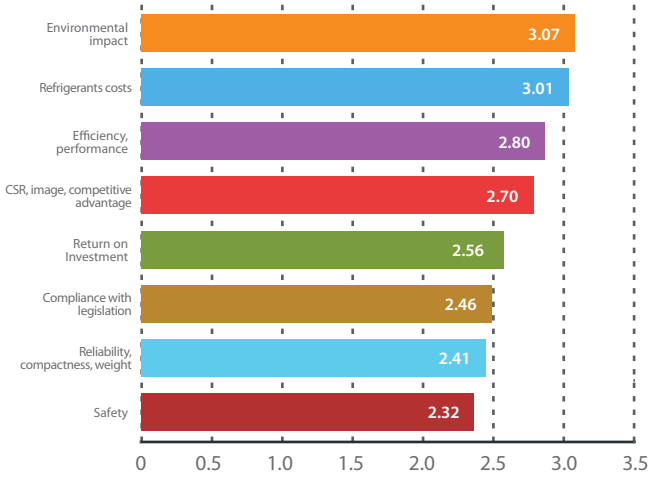
RETURN ON INVESTMENT SINGLE MOST IMPORTANT DECISION FACTOR

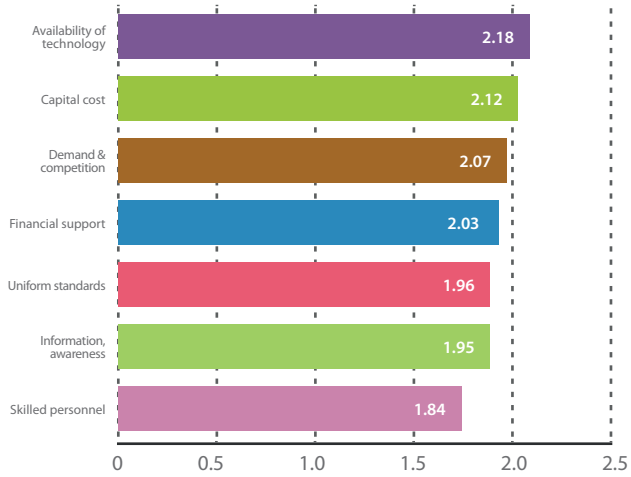
An overwhelming 97.4% of respondents, all those opting for "very important" and "important," believed that commercial / industrial end-users of HVAC&R equipment would decide for the technology that promises the best ROI rate. Even more (97.8%) said this about the initial investment. The highest values for the "not really important" evaluation were seen for the corporate sustainability strategy (28%), for available public financial support (25%), and for a technology's environmental impact (22%). Extracting only those respondents representing end-users, ROI was the most important decision-maiking factor, followed by efficiency and performance, and initial costs.

STRENGHTS & WEAKNESSES OF NATURAL REFRIGERANTS

QUESTION: Rate the following factors as Strengths and Weaknesses that especially apply to Natural Refrigerants. Select from ++ (very strong) to – – (very weak) as compared to conventional refrigerants. O = same as conventional refrigerant systems.

… average values, all respondents





ENVIRONMENT, REFRIGERANT COSTS & EFFICIENCY, CLEAR STRENGTHS

Clear strengths of natural refrigerants (all values above 2.0) were the environmental impact produced by lower direct and indirect emissions, followed by the refrigerant cost, and efficiency benefits. Also among the strengths of NR-based technology in comparison to conventional refrigerants was an enhanced corporate image, lower life cycle costs, reliable technology, and the compliance with current and upcoming legislation. Safety, an area often mentioned as a challenge of NR systems, seems to no longer be considered a major stumbling block for natural refrigerant technology market uptake, by respondents.

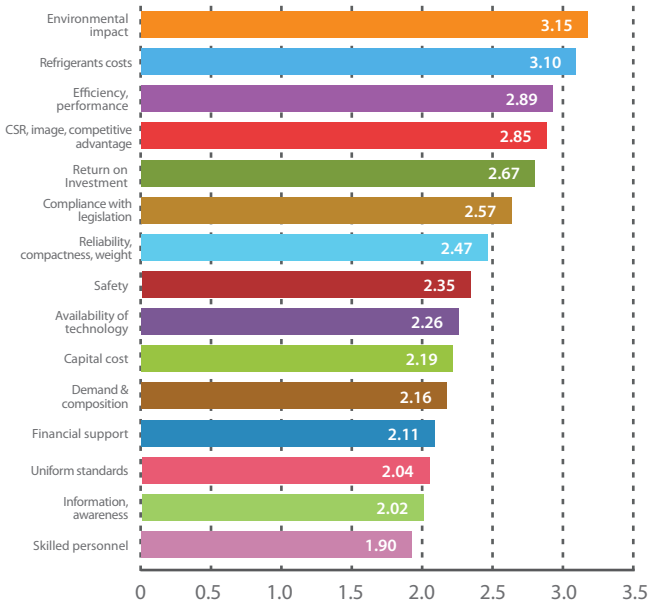
KEY BARRIERS: SKILLED PERSONNEL, AWARENESS & STANDARDS

Only in three fields were natural refrigerants considered to be less competitive than conventional refrigerant-based systems today: the lack of trained personnel was clearly the highest barrier for a faster market uptake, ranked before general awareness and misconceptions arising from a lack of reliable information. The lack of uniform standards in safety, trade, or building codes was the third area in which where NR-based systems faced barriers. The availability of technology and initial investment costs seem to be declining in the importance of their impact as barriers, with average values indicating that NRs performed equally as well as conventional refrigerants.

Total responses: 356

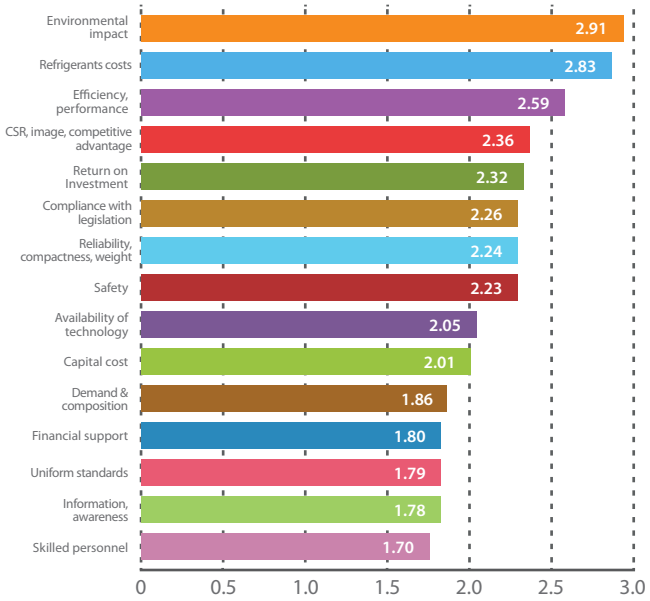
STRENGTHS & WEAKNESSES OF NATURAL REFRIGERANTS

… average values, “NR group”



Total responses: 245

… average values, “non-NR group”



Total responses: 111

NR GROUP

As it could be expected, for the group of respondents that already had or used products or services for natural refrigerants, the evaluation of strengths and weaknesses of natural working fluids, compared to conventional refrigerants, was more positive than for the average respondent. For all values, except for the lack of skilled personnel, the “NR group” thought that natural refrigerants were at least as competitive as conventional fluids in all areas. Again, a reduced environmental impact and low refrigerant costs were noted as clear advantages.

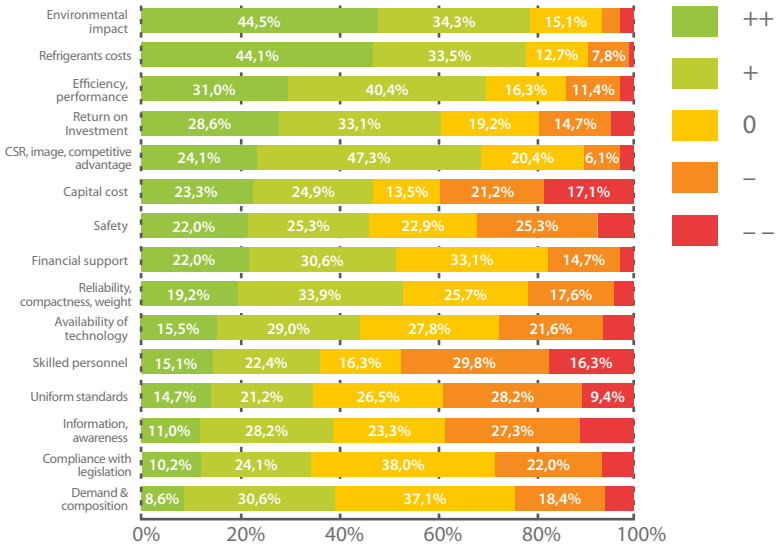
NON-NR GROUP

Unsurprisingly, the average ranking of natural refrigerants versus conventional fluids was consistently lower than for the "NR group." However, the order of strengths and weaknesses remained the same for both groups. Respondents not yet using or offering natural refrigerant products / services estimated that conventional refrigerants would still be more competitive in five areas: the availability of trained technicians, the general awareness and availability of information, the compatibility of standards, the existing market demand and competition levels, as well as the availability of financial support.

STRENGHTS OF NATURAL REFRIGERANTS

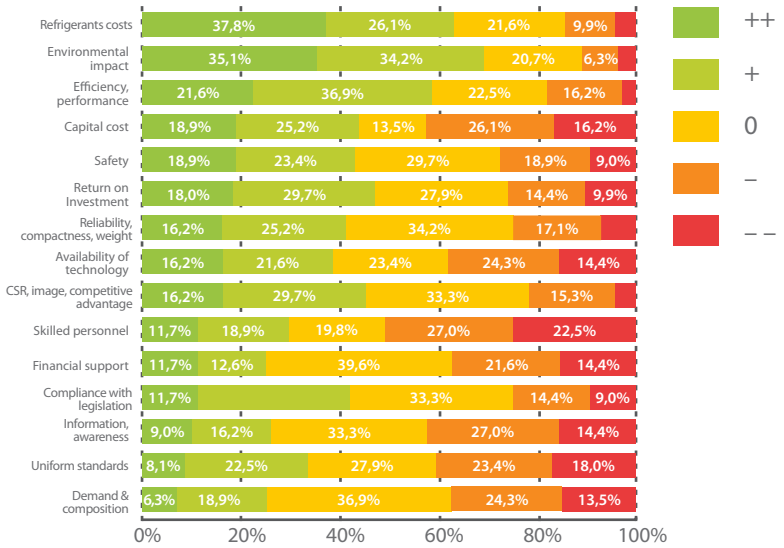
QUESTION: Rate the following factors as Strengths and Weaknesses that especially apply to NaturalRefrigerants. Select from ++ (very strong) to – – (very weak) as compared to conventional refrigerants. O = same as conventional refrigerant systems.

… individual choices, “NR group”



Total responses: 245

… individual choices, “non-NR group”



Total responses: 111

NR GROUP

78% of those already using or offering natural refrigerant technology believed that both environmental impacts from reduced direct and indirect emissions and low refrigerant costs were either “very strong” or “strong” benefits of natural refrigerants. 71% thought that a competitive advantage could be gained by using natural refrigerants and that the performance and efficiency of NR technology was on average, superior. On the other hand, in the field of initial investment costs, more needs to be done, to bring these down as in this category respondents were rather divided in their opinions and the highest share of “very weak” (17%) was recorded.

NON-NR GROUP

69% of respondents not yet using natural refrigerants confirmed that the environmental aspect was a clear benefit of natural refrigerants, followed by 64% for refrigerant costs, and 59% for efficiency and performance. 42% believed capital costs were still a weakness, whereas half of all “non-NR” respondents considered lack of training a barrier (50%).

DECISION FACTORS, STRENGTHS & WEAKNESSES

PURCHASING CRITERIA FOR HVAC&R TECHNOLOGY

Respondents were asked about the importance of individual criteria in the purchasing process of commercial or industrial end-users. A list of 12 criteria in the areas of costs, technology, know-how, policy, and markets was provided. Respondents could rank the individual factors from "not at all important" to "very important."

With values of above 3.7 out of 4.0, the return on investment, as well as initial investment costs remained "very important" purchasing criteria for commercial end-users. These were closely followed by safety (3.5), and efficiency / performance aspects (3.4). With values below 3.0, sustainability commitments (2.8), available financial support from official sources (3.0), and the technology's environmental impact (3.0) were less important and could be found at the lower end of the priority ranking. In the middle, available know-how and trained personnel (3.3) were ranked as "important," as well as reliable supply and familiarity with the technology (3.3) and the influence of standards in the area of safety, trade, and building codes (3.2).

Expressed differently, an overwhelming 97.4% of respondents, all those opting for "very important" and "important," believed that commercial / industrial end-users of HVAC&R equipment would choose the technology that promised the best ROI rate. Even more (97.8%) said this about the initial investment.

If only displaying results for the group of end-users (63 responses), the evaluation changed slightly: 97% of end-users looked at the Return on Investment first ("very important" and "important"), followed, this time, by efficiency and performance of technology second (97%), and then by initial investment (95%). The least relevant decision-making factors for end-users were, starting with the least important, available financial support, achieving a competitive advantage, and CSR / sustainability considerations.

STRENGHTS OF NATURAL REFRIGERANTS

Respondents were asked to directly compare natural refrigerant technology to conventional (HFC, HCFC etc.) refrigerant technology and rank NRs on a 5 point scale from "++" (very strong = 4) to "--" (very weak = 0). All values above 2.0 indicated strengths of NRs when compared to conventional solutions. As was to be expected, clear strengths of natural refrigerants were the reduced environmental impact produced by less direct and indirect emissions (average value of 3.1 out of 4.0), followed by the refrigerant cost (3.0), and efficiency benefits (2.8). Among the strengths of NR-based technology compared to conventional refrigerants were also an enhanced corporate image and competitiveness (2.7), return on investment / lower life cycle costs (2.6), compliance with current and upcoming legislation (2.5), and reliable technology (2.4). Safety – an area often mentioned as a challenge, especially in regards to handling NR systems – seemed no longer to be considered a major stumbling block for natural refrigerants, with a value of 2.3, a similar or slightly better rating than conventional systems.

NR group: When looking at only those who already used NR technology ("NR group"), as could have been expected, the evaluation of strengths and weaknesses of natural working fluids as compared to conventional refrigerants was more positive than for the average respondent. For all values, with the exception of the lack of skilled personnel, the "NR group" thought that natural refrigerants were at least as competitive as conventional fluids in all areas. 78% believed that both environmental impacts from reduced direct and indirect emissions, and low refrigerant costs, were either "very strong" or "strong" benefits of natural refrigerants. 71% thought that a competitive advantage could be gained as a result of using natural refrigerants, and that the performance and efficiency of NR technology was on average, superior.

Non-NR group: 69% of those not yet using natural refrigerants confirm that the environmental aspect is a clear benefit of natural refrigerants, followed by 64% for refrigerant costs, and 59% for efficiency and performance.

WEAKNESSES OF NATURAL REFRIGERANTS

Looking at the lower ratings, one can note that only in three fields were natural refrigerants considered to be less competitive than conventional refrigerants-based systems today. The lack of trained personnel was clearly the highest barrier for a faster market uptake (1.8), coming before the factors general awareness and misconceptions arising from a lack of reliable information (1.9). The lack of uniform standards in safety, trade, or building codes was the third area where NR-based systems faced barriers (1.9). The availability of technology (2.2) and initial investment costs (2.1) seem to be declining in their importance as a concern, with average values indicating that NRs perform equally as well as conventional refrigerants in these areas.

NR group: Only in one field did respondents using NR say that natural refrigerants were less competitive than conventional fluids - the availability of trained technicians. Also, in the field of initial investment costs, more needs to be done, as in this category respondents were rather divided in their opinion and the highest share of "very weak" (17%) was recorded.

Non-NR group: Compared with the above results, the "non-NR" group of respondents estimated that conventional refrigerants would still be more competitive than natural refrigerants in five areas: the lack of trained technicians, the general awareness and availability of information, the compatibility with standards, the existing market demand and competition levels, as well as for available financial support. Specifically, 42% believed capital costs were a weakness, while half of all "non-NR" respondents consider the lack of training a barrier (50%). Interestingly, however, the order of strengths and weaknesses remained the same as in the "NR group".

COMPARISON OF NR STRENGHTS WITH PURCHASING CRITERIA

If we compare findings about the importance of certain purchasing criteria for end-users, with the strengths of natural refrigerants, some interesting conclusions can be drawn. The following table indicates in which areas the requirements of end-users are met by the identified strengths of natural refrigerants. The method used is to look first at the ranking of the purchasing criteria (also reflected as items in the question about strengths). These items (column 1) are ranked from 1 (most important criteria) to 11 (least important criteria) in the second column. Where a range for individual items are indicated for some cells, this specifically takes into account answers from all respondents, and for the sub-set of end-users only (as these are the ones mostly affected). In the next step, the strengths of natural refrigerants are matched in the third column to the respective purchasing criteria. The last column indicates how well natural refrigerants meet expectations by end-users. Green color indicates deviance of 0-3 between both rankings; yellow depicts where purchasing criteria and strengths of NR deviate 4-6; and red indicates were NR do not meet purchasing criteria currently (difference in ranking is higher than 6).

COMPATIBILITY OF NATURAL REFRIGERANTS STRENGTHS WITH PURCHASING CRITERIA

Criteria	Purchasing criteria	Strength	Match
Return on investment	1-3	4	
Capital cost, initial investment	1-2	7	
Safety	2-3	5	
Efficiency / performance	4	2	
Available skilled personnel	5	12	
Availability / supply	6-7	6	
Familiarity	6-7	11	
Available / uniform standards	6-7	10	
Competitive advantage	8-9	8	
Environmental impact	8-9	1	
Available financial support	10-11	9	
Sustainability / CSR / corporate strategy	10-11	3	

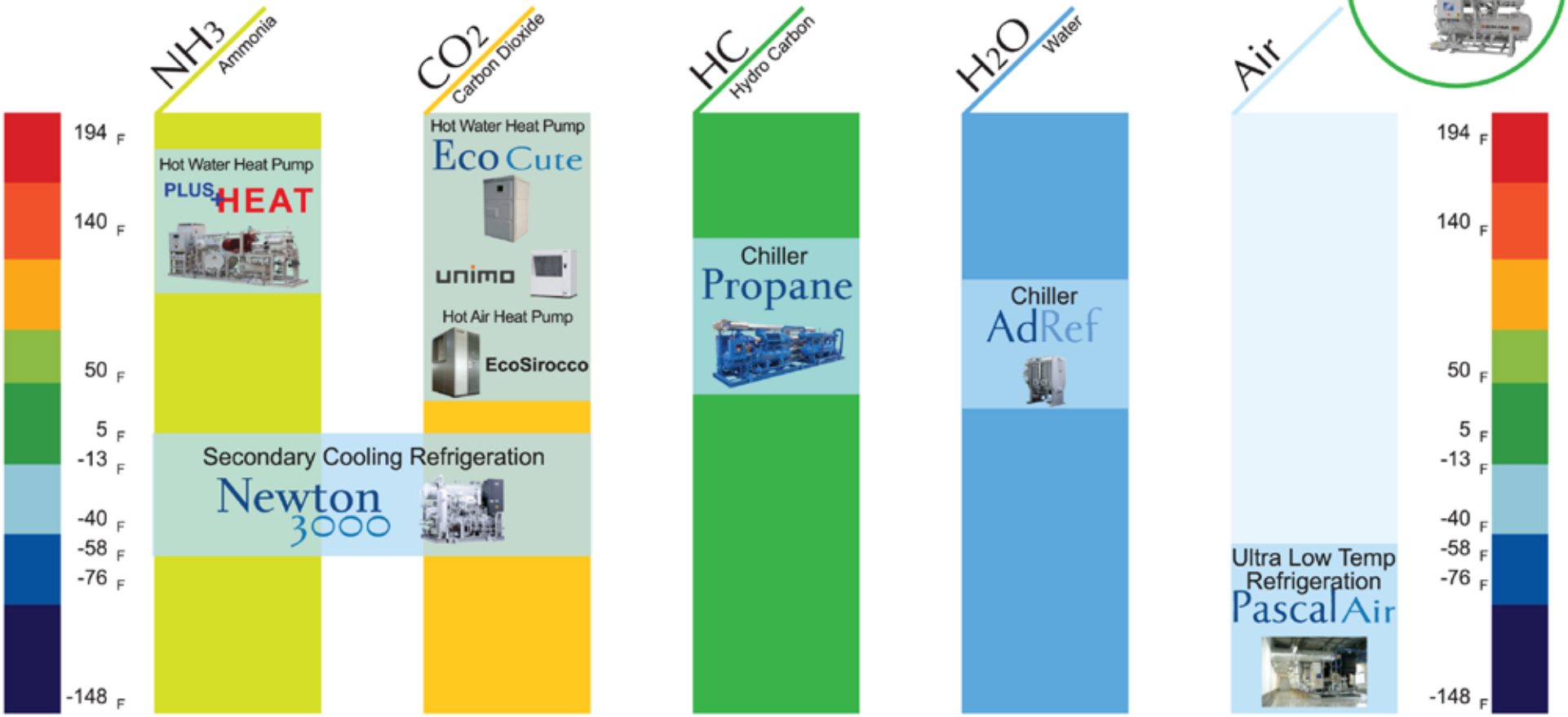
High Compatibility (deviance of 0-3)

Moderate Compatibility (deviance of 4-6)

Low Compatibility (deviance of 7-10)

Your Natural Refrigerant Equipment and Solutions Provider

Natural Five Solutions



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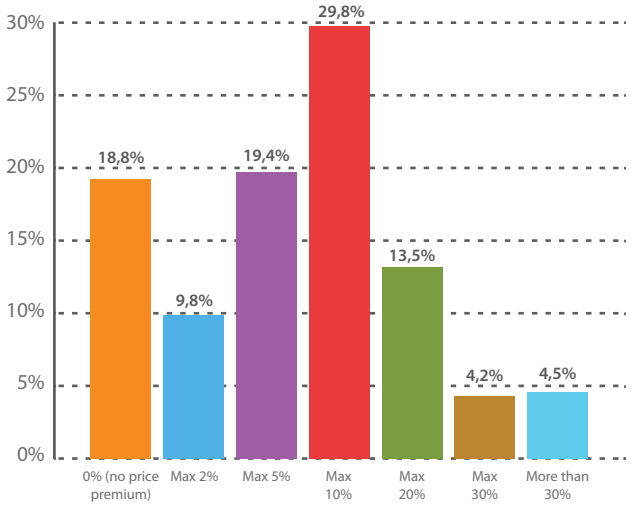
WILLINGNESS TO PAY FOR NATURAL REFRIGERANTS

QUESTION: What is the maximum Price Premium on the initial investment, commercial/ industrial end-users are willing to pay for a Natural Refrigerant application?



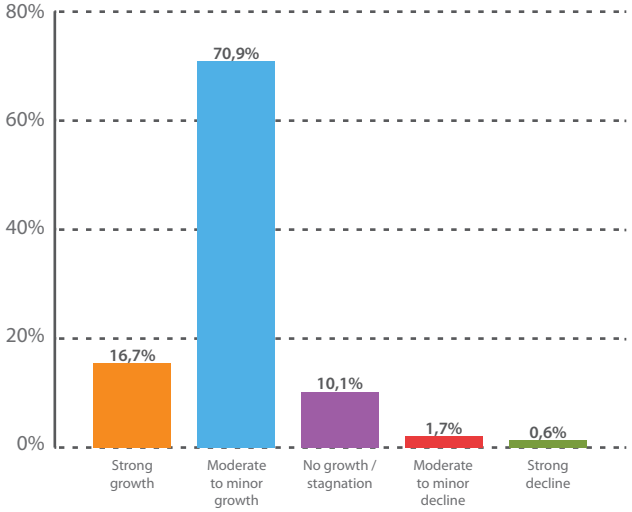
Total responses: 356

MAXIMUM 10% PRICE INCREASE ACCEPTABLE TO END-USERS

Nearly a third of all respondents (30%) believed that end-users would pay up to 10% more for an NR system. 22% believed commercial/industrial end-users would even pay more than that. However, 19% thought that end-users would not accept any price increase, and another 29% expected end-users to only accept a very modest price increase of 2-5%

HVAC&R INDUSTRY OUTLOOK

QUESTION: How do you assess the North American Heating, Air-Conditioning and Refrigeration (HVAC&R) overall Market Development for the period 2012-2014?



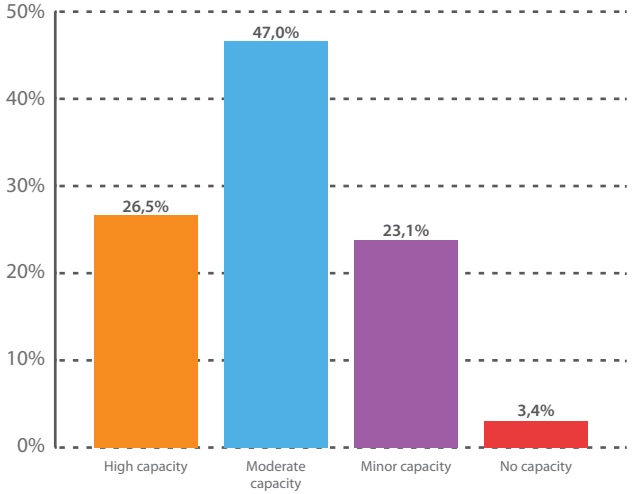
Total responses: 347

HVAC&R INDUSTRY OPTIMISTIC FOR THE NEAR FUTURE

A clear majority of 88% believed that, in the next two years, the North American HVAC&R industry would experience growth, out of which 17% were confident that it would be a "strong growth". 12%, were less optimistic with a tenth of all respondents (10%) sure that it would stagnate.

NORTH AMERICA'S LEADERSHIP POTENTIAL FOR NATURAL REFRIGERANTS

QUESTION: How do you evaluate the overall Capacity of the North American industry to become a World Leader in Natural Refrigerant technology?



Total responses: 381

27% BELIEVE NORTH AMERICA CAN LEAD IN NATURAL REFRIGERANT MARKET

Nearly half of all respondents (47%) believed that North America had a "moderate" capacity to become a world leader in natural working fluids-based technology, with another 27% being even more confident that the region had a "high" potential to lead the world in this area. The remaining quarter of respondents was less optimistic, saying that North America had either a "minor" or "no" capacity to establish itself as a technology leader for natural refrigerants.

NORTH AMERICANS WILLING TO PAY MORE FOR NATURAL REFRIGERANTS. . .

Cost, or the risk of increased cost, is one of the arguments used against the large-scale rollout of natural refrigerant systems. Developing and changing to a new generation of systems is generally costly for both manufacturers and end-users, due to investments in R&D, increased production costs, additional expenditures in up front costs, and investment in technicians' training. In the past, this has led to a 'catch 22 situation' in which manufacturers were not prepared to invest in the research and development of these products without commitments from end-users to source the technology on a longer term basis. End-users, on the other hand, were not willing to pay significantly higher prices for natural refrigerant products whose market viability hadn't been proven yet.

For example, Minneapolis-based Target Corporation experienced an increase in capital investment and maintenance costs, compared to a traditional DX (direct expansion) system using R-404A refrigerant, for the CO_2 systems it tested in two markets.

However, as with the introduction of any new technology, there is a learning curve involved. For Target, each additional CO_2 system installation has resulted in lower costs than the previous one. At the same time retailers' willingness to pay for natural refrigerant systems is increasing. In Canada, where Sobeys has been rapidly deploying transcritical CO_2 systems, these installations are proving to be financially viable in addition to being environmentally friendly. In particular, installation, energy, and maintenance costs have been significantly reduced, in many cases to less than the cost of a synthetic refrigerant system.

The increase in willingness to pay for natural refrigerant systems is reflected in the North American natural refrigerant industry survey, where the majority of end-users (81%) said they would be willing to pay at least 2% more for a natural refrigerant system and over half (52%) said they would be willing to accept at least a 10% increase in price.

. . . BUT WILL ONLY TAKE A MODERATE LEADERSHIP ROLE

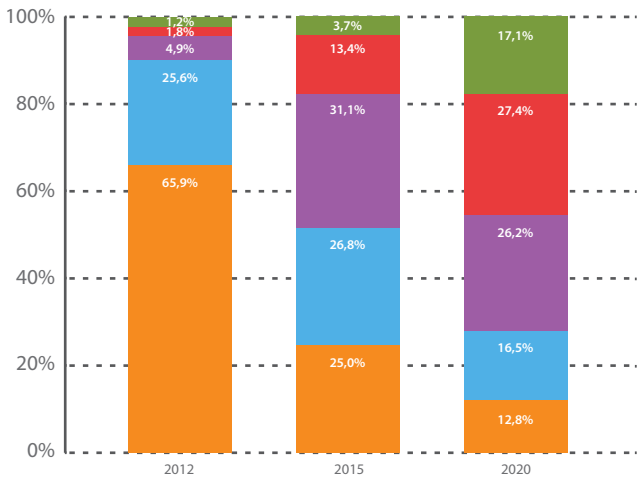
While ammonia already has a strong market share in the industrial refrigeration sector in North America, the development of CO_2 and hydrocarbon HVAC&R solutions began only recently. As a result, the competency of North American companies in supplying natural refrigerant technology to overseas and domestic markets is today assessed as "moderate" by 47% of the natural refrigerant experts, while only a quarter of respondents believe the region has a "high" potential for taking on a leadership role in natural refrigerant technologies.

NATURAL REFRIGERANT MARKET OUTLOOK

COMMERCIAL/LIGHT-COMMERCIAL REFRIGERATION

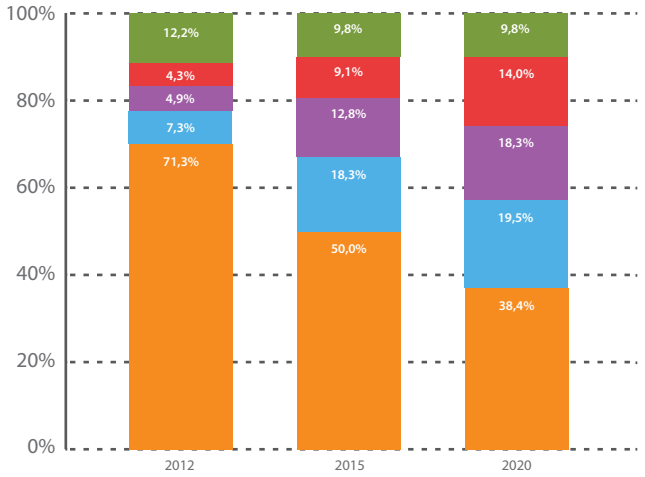
QUESTION: What will be the MARKET SHARE of AMMONIA, CO_2 and HYDROCARBONS at present and in 2015 and 2020 for the Commercial (supermarkets etc.) and Light-Commercial (bottle coolers, plug-in displays, ice cream freezers, vending machines etc.) Refrigeration sector:

CO_2 Commercial Refrigeration



Total responses: 164

Hydrocarbon Commercial Refrigeration



Total responses: 164

CO_2 COMMERCIAL REFRIGERATION

According to the 164 respondents to this question, CO_2 shows strong potential for rapid market growth in commercial refrigeration in North America. Although two-thirds say the market for CO_2 is still a niche market today (0-5%), 58% believe its market share will grow to 6-20% by 2015, and 45% of respondents are confident that the market share of CO_2 refrigerant will rise to more than 20% by 2020.

HYDROCARBON COMMERCIAL REFRIGERATION

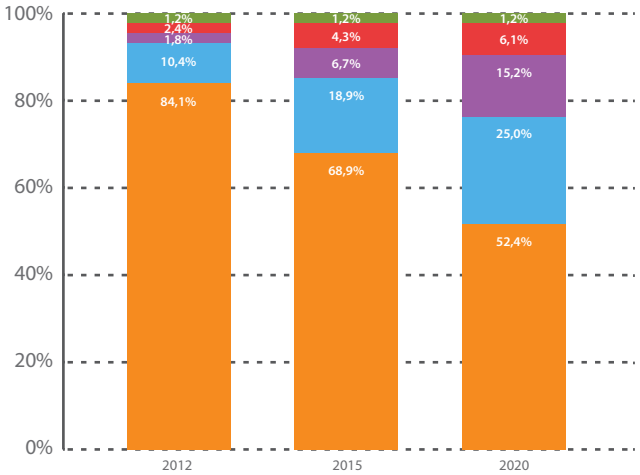
Although the number of HC installation in commercial refrigeration is still low today, thought to be in the "0-5%" market share range, 42% of respondents believe that their use will grow to more than a 10% market share by 2020. Every tenth respondent believes a market share of "more than 50%" could be possible by then. However, markets will not be moving as fast as for CO_2, with half of all respondents still predicting a market share of HCs of below 5% in the next 3 years.

NATURAL REFRIGERANT MARKET OUTLOOK

COMMERCIAL/LIGHT-COMMERCIAL REFRIGERATION

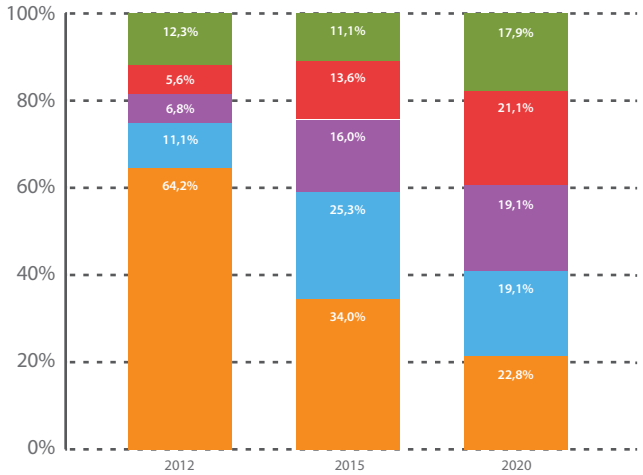
QUESTION: What will be the MARKET SHARE of AMMONIA, CO_2 and HYDROCARBONS at present and in 2015 and 2020 for the Commercial (supermarkets etc) and Light-Commercial (bottle coolers, plug-in displays, ice cream freezers, vending machines etc) Refrigeration sector:

Ammonia Commercial Refrigeration

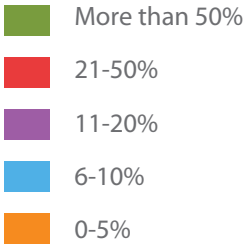


Total responses: 164

Hydrocarbon Light-Commercial Refrigeration



Total responses: 162



AMMONIA COMMERCIAL REFRIGERATION

A majority of the 164 respondents (84%) believe that ammonia refrigeration for commercial applications still remains a small market (0-5%) today. Nearly a third (31%) believe ammonia's market share will have increased to more than 5% by 2015. Nearly half (48%) of the respondents are confident that ammonia will experience gradual growth and cover more than 5% of the commercial refrigeration market by 2020.

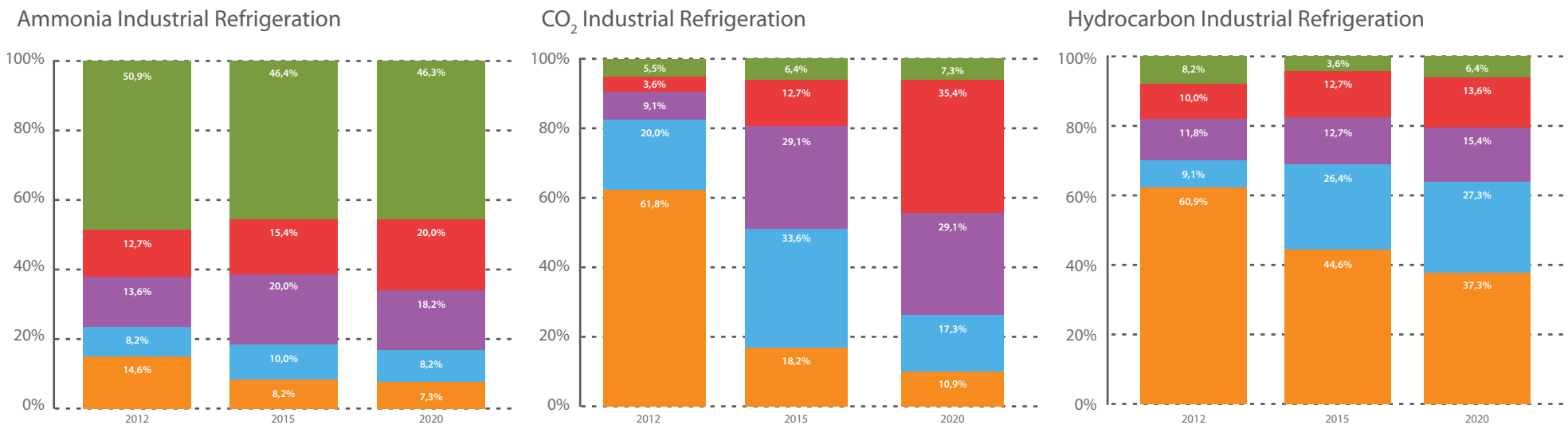
HYDROCARBON LIGHT-COMMERCIAL REFRIGERATION

Hydrocarbons are more commonly used in, and have the largest potential for growth, in the light commercial refrigeration sector in the North American market. 66% of the 162 respondents believe the market share of hydrocarbons will have reached more than 5% by 2015. This number grows to 77% by 2020, when 39% say the market share has the potential to be even larger than 20%.

NATURAL REFRIGERANT MARKET OUTLOOK

INDUSTRIAL REFRIGERATION

QUESTION: What will be the MARKET SHARE of AMMONIA, CO_2 and HYDROCARBONS at present and in 2015 and 2020 for the Industrial Refrigeration sector:



Total responses: 110

Total responses: 110

Total responses: 110

AMMONIA INDUSTRIAL REFRIGERATION

In North America, the market for ammonia industrial refrigeration is already mature. More than half of all respondents (51%) believe the market share of ammonia is currently more than 50%. The growth potential for ammonia is therefore not as pronounced as for other natural refrigerants, as it is widely used today. Respondents predict that while ammonia will continue to largely dominate the industrial refrigeration market in the future, new technology developments and refrigerants could have a slight impact on its dominance.

CO_2 INDUSTRIAL REFRIGERATION

CO_2 is now more commonly used in industrial refrigeration and its market share is growing rapidly in North America. 63% of the respondents are confident the market share will increase to 6-20% by 2015. A large majority (72%) believes CO_2 industrial refrigeration could reach more than a 10% market share by 2020. Although most respondents do not think CO_2 will dominate the future market (>50%), 35% still believe that CO_2 could play a more important role in industrial refrigeration than it does now and that its market share could reach 20-50% by 2020.

HYDROCARBON INDUSTRIAL REFRIGERATION

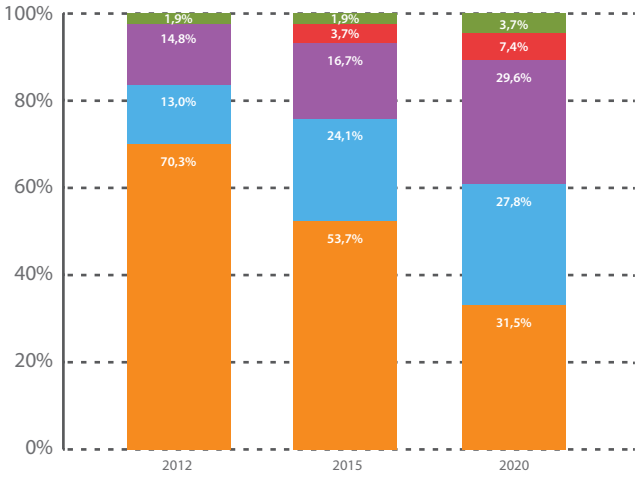
Although 70% of the 110 industrial experts say the market share of hydrocarbons is less than 10% today, a clear majority (55%) indicate that hydrocarbons have the potential to account for more than 5% market share by 2015, and 35% of experts believe hydrocarbons' market share will be larger than 10% by 2020.

NATURAL REFRIGERANT MARKET OUTLOOK

STATIONARY A/C

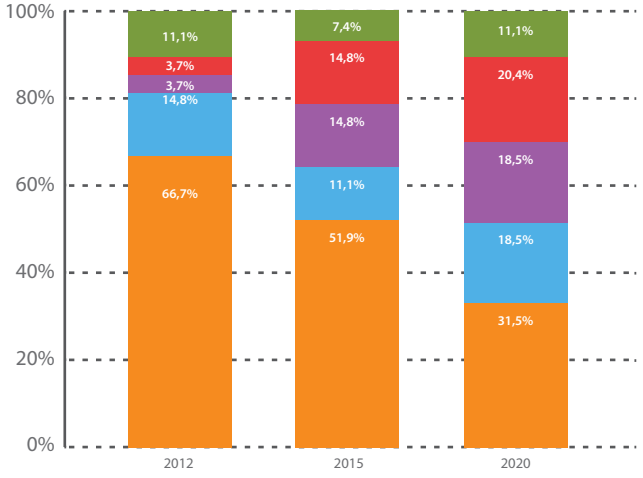
QUESTION: What will be the MARKET SHARE of AMMONIA, CO_2 and HYDROCARBONS at present and in 2015 and 2020 for the Stationary Air Conditioning (A/C) sector:

Ammonia Stationary A/C

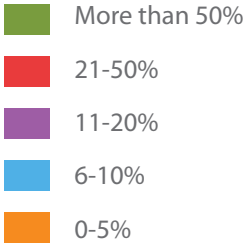


Total responses: 54

Hydrocarbon Stationary A/C



Total responses: 54



AMMONIA STATIONARY A/C

Ammonia has not been used to a large extent in industrial air conditioning in North America. 70% of the 54 industrial experts in this field regard its market share to be less than 5%. However, nearly half (46%) believe the market for ammonia will grow to more than 5% by 2015 and 41% say its market share will be more than 10% by 2020.

HYDROCARBON STATIONARY A/C

Hydrocarbons (HC) have already been applied in the residential air conditioning sector in North America. 48% of the 54 industrial experts in the survey specialized in the air-conditioning sector indicate there is a large growth potential for hydrocarbons in residential A/C and its market share is likely to exceed 5% by 2015. 50% even believe the market share of HC technology solutions will be larger than 10% by 2020.

MARKET FORECASTS UNTIL 2020

The first part of the North American natural refrigerant industry survey, which was answered by 559 individuals, was uniform for all respondents. In the second part of the survey, individuals had to select their field of expertise among six different industry sectors: heating (residential, commercial, and industrial), refrigeration (domestic), refrigeration (commercial), refrigeration (industrial), air conditioning (stationary), and air conditioning (mobile). Mobile air conditioning and heating were excluded in the final results due to a lack of data.

Each industry sector was represented to a different extent, ranging from just over 164 responses for the commercial refrigeration sector, 162 responses for the light commercial refrigeration sector, 110 responses for the industrial refrigeration sector, 54 responses for the stationary AC sector, and 22 responses for the domestic refrigeration sector, to 21 responses for the mobile air conditioning sector.

The high response rate for the commercial and light commercial refrigeration sectors confirms that there is a growing interest in natural refrigerant technologies in these areas, particularly concerning CO_2 technology for supermarkets and hydrocarbons, which were SNAP approved in 2012, for applications like ice cream freezers and bottle coolers.

RAPIDLY EXPANDING MARKETS

Retailers have started exploring refrigeration systems that incorporate CO_2 and other natural refrigerants, such as ammonia and hydrocarbons, in the hopes of reducing or even eliminating entirely their use of synthetic refrigerants. This has been one of the major HVAC&R developments in North America in recent years. In the US, several retailers have invested in CO_2 secondary or cascade systems, while in Canada, the number of CO_2 transcritical installations is on the rise. Despite the fact that with just over 120 installations, the equivalent of 0-5% of the market share, CO_2 refrigeration applications currently represent only a niche market in North America, almost half of the natural refrigerant commercial refrigeration experts (45%) believed that by 2020, the market share of CO_2 could rise to more than 20%. In fact, CO_2 in commercial refrigeration was expected to be the most rapidly expanding natural refrigerant market.

MODEST GROWTH MARKETS

Hydrocarbons represent a more modest growth market for the commercial refrigeration sector. Almost half (42%) of those questioned responded that hydrocarbons would have a market share of more than 10% by 2020. It should be noted that, without changes to standards, laws, and regulations, the 150g charge limit per system constrains the transition to hydrocarbons in the commercial refrigeration sector. In all likelihood, this is reflected in the prediction that hydrocarbons would have a lower market share than CO_2. Ammonia ranked third in predictions for market growth in the commercial refrigeration sector. Nearly half (48%) of respondents forecast a market share above 5% for ammonia by 2020. Historically, fears concerning toxicity have hindered the wide scale use of ammonia in North American supermarkets. However, thanks to significant improvements in system design, reductions in charge sizes, and better safety features, several retail chains are now using ammonia cascade systems in pilot projects.

In the industrial refrigeration sector a significant change in the market share of CO_2 and hydrocarbons is expected. The majority (72%) of respondents believed that, by 2020, CO_2 industrial refrigeration could reach a market share of more than 10%. A third (35%) of respondents thought that hydrocarbon industrial refrigeration could reach a market share of more than 10%.

For stationary AC, the market share for ammonia has the potential to grow to more than 10% by 2020, according to 41% of respondents. Respondents assume a market share of less than 5% in today's markets. Half of respondents also believe that the market share of hydrocarbon technology will exceed 10% by 2020.

STABLE MARKETS

In the industrial refrigeration market, ammonia has long been the preferred refrigerant for many applications, in particular in the food industry. This was evident in the survey responses. Half of respondents (51%) believe the market share of ammonia in industrial refrigeration to be more than 50% today, decreasing ever so slightly in 2020 to 46% of respondents. Interestingly, it is widely reported that ammonia has a 95% penetration in the industrial refrigeration sector, which, when compared to the survey responses, suggests that respondents are hesitant to paint too positive a picture for natural refrigerants, even when it comes to an established technology such as ammonia.

ATMOsphere AMERICA business case natural refrigerants

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OTHER UPCOMING ATMOsphere EVENTS

ATMOsphere UN technology summit natural solutions 3 - 4 June 2013 in Vienna

UNIDO ATMOsphere Technology Summit 2013 - Natural Solutions for Developing Countries

3 - 4 June 2013, Vienna, Austria

ATMOsphere ASIA technology & innovation natural refrigerants 17-19 September 2013 in Tokyo

ATMOsphere Asia 2013 - Technology & Innovation

17-19 September 2013, Tokyo, Japan

More information on these and other ATMOsphere events coming soon.

www.ATMO.org

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http://www.epa.gov/ozone/snap/refrigerants/reflist.pdf
[Accessed 30 January 2013]

DIRECTORY

Business Directory – the GUIDE concludes with a directory of North American-based companies, associations, end users, and international organizations already involved in natural refrigerants today.

This industry directory, based largely on responses to a North American HVAC&R industry survey conducted in 2012, lists and categorizes system manufacturers, component suppliers, contractors, installers, NGOs, government agencies and research & training institutes located in North America.

Sorted by country, it indicates the type of activities, main HVAC&R industry sectors covered, as well as the natural refrigerants used in products and services. As the directory only reflects information provided on a voluntary basis by the respective organizations, no responsibility for accuracy is assumed.

If you want to be included in later editions of the Guide 2013: Natural Refrigerants Market Growth for North America or other world regions, please contact: research@shecco.com

HVAC&R SYSTEM & COMPONENT MANUFACTURERS & ENGINEERING CONTRACTORS

CANADA

Accent Refrigeration Systems Ltd
www.accent-refrigeration.com

System Manufacturer
Engineering / Contractor
Training / Research

Heating - Industrial & Commercial
Refrigeration - Industrial
Air Conditioning - Industrial & Commercial

206 - 1097 Langford Parkway, Victoria
V9B0A5 British Columbia, Canada

001 250 478-8885

Arneg Canada
www.arneg.ca

System Manufacturer

Refrigeration - Light-Commercial

18 Richelieu, Lacolle
J0J 1J0 Québec, Canada

001 450 246 3837

Berg
www.berg-group.com

System Manufacturer

Refrigeration - Industrial

51 Nantucket Boulevard, Toronto
M1P 2N5 Ontario, Canada

001 4160 755 2221

BITZER Canada Inc.
www.bitzer.ca

Component Supplier

Refrigeration - Commercial
Refrigeration - Industrial
Refrigeration - Transport
Air Conditioning - Industrial & Commercial

930 Selkirk Street, Pointe Claire
QC H9R 4T7 Québec, Canada

001 514 697 3363

Black & Mac

Engineering / Contractor

Refrigeration - Industrial

105-20 tuxedo court, Scarborough
M1G 3S5 Ontario, Canada

Black & McDonald
www.blackandmcdonald.com

Engineering / Contractor

Air Conditioning - Industrial & Commercial

Suite 2100 - 2 Bloor Street East, Toronto
M4W 1A8 Ontario, Canada

001 416 920 5100

Bronswerk
www.bronswerkgroup.com

System Manufacturer

Refrigeration - Industrial

4050 Place de Java, Brossard
J4Y 0C4 Québec, Canada

001 450 659 6571

CO_2 HC NH_3 H_2O AIR

CanmetENERGY
www.canmetenergy.nrcan.gc.ca

Engineering / Contractor
Consultancy / Marketing
Training / Research

Heating - Industrial & Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Industrial & Commercial

1615 Boul. Lionel-Boulet, Varennes
J3X 1S6 Québec, Canada

CO_2 HC NH_3 H_2O AIR

Carnot Réfrigération
www.carnotrefrigeration.com

System Manufacturer

Refrigeration - Commercial
Refrigeration - Industrial

3368, Rue Bellefeuille, Trois-Rivières
G9A 3Z3 Québec, Canada

001 819 376 5958

CO_2 HC NH_3 H_2O AIR

Chinook Refrigeration
www.chinookrefrigeration.com

Engineering / Contractor

Heating - Industrial & Commercial
Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Industrial & Commercial

1130e 44ave SE, Calgary
T2G 4W6 Alberta, Canada

001 403 243 0141

CO_2 HC NH_3 H_2O AIR

CT Control Temp
www.ctcontroltemp.com

Engineering / Contractor

Refrigeration - Commercial

4340 Dawson Street, Burnaby
V5C 4B6 British Columbia, Canada

001 604 298 2000

CO_2 HC NH_3 H_2O AIR

Duracool
www.duracool.com

Refrigerant Supplier

2695 Slough Street, Mississauga
L4T 1G2 Ontario, Canada

001 905 671 4222

CO_2 HC NH_3 H_2O AIR

Emerson Climate Technologies Canada
www.emersoncanada.ca

Component Supplier
System Manufacturer

Refrigeration - Domestic
Refrigeration - Commercial
Refrigeration - Industrial
Refrigeration - Transport
Air Conditioning - Stationary
Air Conditioning - Mobile

306 Town Center Blvd., Markham
L3R 0Y6 Ontario, Canada

001 905 948 3400

CO_2 HC NH_3 H_2O AIR

Fixair
www.fixair.qc.ca

Engineering / Contractor

Refrigeration - Industrial

3149 Delaunay, Laval
H7L 5A4 Québec, Canada

001 450 688 4673

CO_2 HC NH_3 H_2O AIR

Groupe Master
www.master.ca

Component Supplier

Heating - Residential
Heating - Industrial & Commercial
Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Residential
Air Conditioning - Industrial & Commercial

1675, Boul. de Montarville, Boucherville
J4B 7W4 Québec, Canada

001 514 527 2301

CO_2 HC NH_3 H_2O AIR

Henry Technologies Ltd.

www.henrytech.com

Component Supplier

Heating - Industrial & Commercial
Refrigeration - Commercial
Refrigeration - Industrial

P.O. BOX 1385, Brantford
N3T 5T6 Ontario, Canada

001 519 759 3010

CO_2 HC NH_3 H_2O AIR

KeepRite Refrigeration

www.k-rp.com

System Manufacturer

Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Industrial & Commercial

18104 102 Ave NW
T5S 1S7 Alberta, Canada

001 780 930 7066

CO_2 HC NH_3 H_2O AIR

LESAGE INC.

www.lesageinc.com

System Manufacturer

Heating - Residential & Building
Heating - Industrial & Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Refrigeration - Transport
Air Conditioning - Stationary

817 Salaberry, Laval
H7S 1H5 Québec, Canada

001 514 337 3585

CO_2 HC NH_3 H_2O AIR

Liebherr

www.liebherr.ca

System Manufacturer

Refrigeration - Domestic
Refrigeration - Light-Commercial

1015 Sutton Drive, Burlington
L7L 5Z8 Ontario, Canada

001 905 319 9222

CO_2 HC NH_3 H_2O AIR

Linde Group

www.lindecanada.com

Engineering Company
Refrigerant Supplier

5860 Chedworth Way, Mississauga
L5R 0A2 Ontario, Canada

CO_2 HC NH_3 H_2O AIR

Minus Forty

www.minusforty.com

System Manufacturer

30 Armstrong Ave., Georgetown
L7G 4R9 Ontario, Canada

001 905 702 1441

CO_2 HC NH_3 H_2O AIR

NDL INDUSTRIE S INC.

www.ndlinc.com

Component Supplier

Refrigeration - Commercial

266 SW Marine Drive, Vancouver
V5X 2R5 British Colombia, Canada

001 604 736 7470

CO_2 HC NH_3 H_2O AIR

QBD Cooling Systems Inc

www.qbd.com

System Manufacturer

Refrigeration - Light-Commercial

31 Bramsteele Rd, Brampton
L6W 3K6 Ontario, Canada

001 800 663 3005

CO_2 HC NH_3 H_2O AIR

Refplus Inc.

www.refplus.com

System Manufacturer

Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Industrial & Commercial

2777, Grande Allée, Saint-Hubert
J4T 2R4 Québec, Canada

001 450 641 2665

CO_2 HC NH_3 H_2O AIR

Refrigeration Components Canada
www.refrigerationcomponents.ca

Component Supplier

Refrigeration - Commercial
Refrigeration - Industrial

111-7359 72nd St., Delta
V4G 1H9 British Columbia, Canada

001 604 940 9951

CO_2 HC NH_3 H_2O AIR

RMC
www.refrigerantmanagement.ca

Engineering / Contractor

Heating - Industrial & Commercial
Refrigeration - Industrial
Air Conditioning - Stationary

2800 Skymark Ave, Building 1, suite 201,
Mississauga, L4W 5A6 Ontario, Canada

001 905 361 1165
001 866 622 0209

CO_2 HC NH_3 H_2O AIR

RP Muller inc
www.rpmuller.com

Engineering / Contractor

Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Industrial & Commercial

5500 Vanden Abeele, St-Laurent
H4S 1P9 Quebec, Canada

001 514 697 3997

CO_2 HC NH_3 H_2O AIR

UNIQUE
www.uniqueoffgrid.com

Refrigeration - Light-Commercial

2245 Wyecroft Road No 5, Oakville
L6L 5L7 Ontario, Canada

001 905 827 6154

CO_2 HC NH_3 H_2O AIR

MEXICO

ABE
www.abe-ref.com

System Manufacturer

Refrigeration - Industrial

A. Blasquez E. Refrigeración Industrial S.A.
de C.V. Av. Contreras No. 516 Piso 5 Col. San
Jerónimo Lídice, Mexico

0052 56 836 288
0052 56 836 788

CO_2 HC NH_3 H_2O AIR

Alfa Laval SA de CV
www.alfalaval.com

Component Supplier

Heating - Residential
Heating - Industrial & Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Industrial & Commercial

Vía Gustavo Baz No 352, Col La Loma,
Tlalnepantla 54060 Estado de Mexico, Mexico

0052 55 300 327 00

CO_2 HC NH_3 H_2O AIR

Ecofreeze
www.ecofreezeinternational.com

Refrigerant Supplier

Pabellón TEC 21 y 21, Garza Sada 427 Sur,
Monterrey, Nuevo León, Mexico

0052 81 113 383 40
0052 81 123 414 07

CO_2 HC NH_3 H_2O AIR

Funcosa
www.funcosa.com.mx

Component Supplier

Heating - Residential

Toluca, Mexico

0052 214 43 70
0052 214 43 77

CO_2 HC NH_3 H_2O AIR

Imbera
www.imbera.mx

System Manufacturer
Consultancy / Marketing

Refrigeration - Commercial

Carretara Mexico Tequisquiapan Km3.2, Zona Industrial, San Juan del Rio
76800 Querétaro, Mexico

0052 427 271 8000

CO_2 HC NH_3 H_2O AIR

USA

A.S. Trust & Holdings Inc
www.hcr188c.com

Refrigerant Supplier
Refrigeration - Domestic
Commercial refrigeration

44-129 Mikiola Drive, Kaneohe
96744 Hawaii, USA

001 808 235 1890

CO_2 HC NH_3 H_2O AIR

ACC - Group
www.the-acc-group.com

Component Supplier

Refrigeration - Domestic

PO Box 875,
35056 Alabama, USA

CO_2 HC NH_3 H_2O AIR

ACC Climate Control
www.accclimatecontrol.com

System Manufacturer

Heating - Industrial & Commercial
Air Conditioning - Mobile

22428 Elkhart East Boulevard, PO Box 1905
46514 Indiana, USA

001 574 264 2190

CO_2 HC NH_3 H_2O AIR

Agramkow
www.agramkow.com

End of line solutions

1200 Woodruff Rd A3, USA

001 864 297 9999

CO_2 HC NH_3 H_2O AIR

AHT Cooling Systems
www.aht.at/us/home/home.asp

System Manufacturer

Refrigeration - Commercial

1005 Bankton Circle, Hanahan
29406 South Carolina, USA

001 843 266 1756

CO_2 HC NH_3 H_2O AIR

AIR
www.airefrig.com

System Manufacturer
Engineering / Contractor

Heating - Industrial & Commercial
Refrigeration - Industrial
Air Conditioning - Industrial & Commercial

14322 21st Avenue N., Plymouth
55447 Minnesota, USA

001 952 470 9610

CO_2 HC NH_3 H_2O AIR

Air Prodcucts
www.airproducts.com

Refrigerant Supplier

7201 Hamilton Blvd, Allentown
18195-1501 Pennsylvania, USA

001 610 481 4911

CO_2 HC NH_3 H_2O AIR

Airgas Specialty Products
www.airgasspecialtyproducts.com

Training

2530 Sever Road, Suite 300, Lawrenceville
30043 Georgia, USA

001 800 295 2225

CO_2 HC NH_3 H_2O AIR

Alfa Laval
www.alfalaval.com

Component Supplier

Heating - Residential & Building
Heating - Industrial & Commercial
Refrigeration - Domestic
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Stationary

5400 International Trade Drive, Richmond
23231 Virginia, USA

001 804 222 5300

CO_2 HC NH_3 H_2O AIR

Amco Mechanical Inc
www.amcomechanical.com

Engineering / Contractor

231 E Emerson Avenue, Orange
92865 California, USA

001 714 279 8039

CO_2 HC NH_3 H_2O AIR

American Industrial Refrigeration
www.airefrig.com

System Manufacturer

Refrigeration - Industrial

14322 21st Ave. N., Plymouth
55447 Minnesota, USA

001 952 470 9610

CO_2 HC NH_3 H_2O AIR

American Sensor Technologies
www.astsensors.com

Component Supplier

Refrigeration - Industrial

450 Clark Dr., Mt. Olive
07828 New Jersey, USA

001 973 448 1901

CO_2 HC NH_3 H_2O AIR

Ammonia Refrigeration Service
www.ammoniarefrigeration.com

System Manufacturer

Refrigeration - Industrial

278 Main Street, P.O. Box 898, Loganville
30052 Georgia, USA

001 770 466 8630

CO_2 HC NH_3 H_2O AIR

APCCO
www.apcco.net

System Manufacturer

Refrigeration - Industrial

4812 Enterprise Way, Modesto
95356 California, USA

001 209 578 1000

CO_2 HC NH_3 H_2O AIR

Apex
www.apexrefrig.com

Engineering / Contractor
Consultancy / Marketing

Heating - Industrial & Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Refrigeration - Transport
Air Conditioning - Industrial & Commercial

2930 West Willetta Street, Phoenix
85009 Arizona, USA

001 602 864 1600

CO_2 HC NH_3 H_2O AIR

Bacharach
www.bacharach-inc.com

Component Supplier

Refrigeration - Industrial

621 Hunt Valley Circle, New Kensignton
15068-7074 Pennsylvania, USA

001 724 334 5000

CO_2 HC NH_3 H_2O AIR

Baltimore Aircoil Company
www.baltimoreaircoil.com

System Manufacturer

Refrigeration - Commercial
Refrigeration - Industrial

7600 Dorsey Run Road, Jessup
20794 Maryland, USA

001 410 799 6200

CO_2 HC NH_3 H_2O AIR

Blissfield Manufacturing Co.
www.blissfield.com

System Manufacturer

Refrigeration - Commercial

626 Depot Street, Blissfield
49228 Michigan, USA

001 517 486 2121

CO_2 HC NH_3 H_2O AIR

Bonar Engineering & Construction Company
www.bonareng.com

System Manufacturer

Refrigeration - Industrial

565 South Edgewood Avenue, Jacksonville
32205 Florida, USA

001 228 627 1986

CO_2 HC NH_3 H_2O AIR

C&L Refrigeration
www.clrefrigeration.com

Engineering / Contractor

Refrigeration - Industrial

479 Nibus St., Brea
92821 California, USA

001 800 901 4822

CO_2 HC NH_3 H_2O AIR

CAMCO Lubricants
www.camcolubricants.com

Component Supplier

Refrigeration - Industrial

1441 Rice Street, St. Paul
55117 Minnesota, USA

001 651 489 8828

CO_2 HC NH_3 H_2O AIR

Carel USA
www.carelusa.com

Component Supplier

Refrigeration - Domestic
Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Refrigeration - Transport
Air Conditioning - Residential
Air Conditioning - Industrial & Commercial
Air Conditioning - Mobile

385 South Oak Street, Manheim
17545 Pennsylvania, USA

001 717 664 0500

CO_2 HC NH_3 H_2O AIR

Carrier
www.carrier.com

System Manufacturer

Heating - Residential & Building
Heating - Industrial & Commercial
Refrigeration - Commercial
Refrigeration - Transport
Air Conditioning - Residential
Air Conditioning - Industrial & Commercial

One Carrier Place, Farmington
06034-4015 Connecticut, USA

001 800 227 7437

CO_2 HC NH_3 H_2O AIR

CEC
www.controlledenvironments.com

Component Supplier
Engineering / Contractor
Consultancy / Marketing

Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Industrial & Commercial

1542 Edinger Ave., Tustin
92780 California, USA

001 714 566 9090

CO_2 HC NH_3 H_2O AIR

ChemicaLogic Corporation
www.chemicalogic.com

Consultancy / Marketing

Refrigeration - Industrial

99 S. Bedford Street, STE 207, Burlington
1803 Massachusetts, USA

001 781 425 6738

CO_2 HC NH_3 H_2O AIR

Cimco Refrigeration
www.cimcorefrigeration.com

System Manufacturer
Component Supplier
Engineering / Contractor

Refrigeration - Industrial

65 Villiers Street, Toronto
M5A 3S1 Ontario, USA

001 416 465 7581

CO_2 HC NH_3 H_2O AIR

CO2meter.com
www.co2meter.com

Component Supplier

131 Business Center Drive, Building A, Unit 3,
Ormond Beach, 32174 Florida, USA

001 386 310 4933

CO_2 HC NH_3 H_2O AIR

Colmac Coil Manufacturing Inc.
www.colmaccoil.com

System Manufacturer

Refrigeration - Commercial

370 N Lincoln St, Colville
99114-0571 Washington, USA

15096842595

CO_2 HC NH_3 H_2O AIR

ComStar
www.comstarproducts.com

Refrigerant Supplier
Refrigeration - Light-Commercial
Refrigeration - Commercial

20-45 128th Street, College Point
11356 New York, USA

001 718 445 7900

CO_2 HC NH_3 H_2O AIR

Continental Case Company LLC
www.contcase.com

Manufacturer of Replacement Parts

Refrigeration - Commercial

2 Northfield Plaza, Suite 210, Northfield
60093 Illinois, USA

001 847 441 2950

CO_2 HC NH_3 H_2O AIR

Cool Air
www.coolairinc.com

Component Supplier

Refrigeration - Industrial

1441 Rice Street, St. Paul
55117 Minnesota, USA

001 651 487 8844

CO_2 HC NH_3 H_2O AIR

Cool Solutions
www.coolsolutionsco.com

Engineering Contractor

5007 Lincoln Avenue, Suite 201
60532 Illinois, USA

001 630 353 9690

CO_2 HC NH_3 H_2O AIR

Cooling International LLC
www.coolinginternational.com

Engineering / Contractor

Refrigeration - Industrial

4744F North Royal Atlanta Dr., Tucker
30084 Georgia, USA

001 770 493 1244
001 770 493 1245

CO_2 HC NH_3 H_2O AIR

Core Enterprises Inc.
www.core-enterprises.com

System Manufacturer

3650 Coral Ridge Drive, Suite 101, Coral Springs
33065 Florida, USA

001 954 227 0781

CO2 HC NH3 H2O AIR

Cotherm of America Corporation
www.cotherma.com

Consultancy / Marketing

Heating - Industrial & Commercial
Air Conditioning - Industrial & Commercial

3005 SW 25 Street, Fort Lauderdale
33312 Florida, USA

001 954 376 6019

CO2 HC NH3 H2O AIR

Creative Thermal Solutions
www.creativethermalsolutions.com

Training / Research

Heating - Residential
Heating - Industrial & Commercial
Refrigeration - Domestic
Refrigeration - Light-Commercial
Air Conditioning - Residential
Air Conditioning - Industrial & Commercial
Air Conditioning - Mobile

2209 N Willow Rd, Urbana
61802 Illinois, USA

001 217 344 7663

CO2 HC NH3 H2O AIR

CTA Architects Engineers
www.ctagroup.com

Engineering / Contractor

Heating - Industrial & Commercial
Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Industrial & Commercial

1185 Grove Street, Boise
83702 Idaho, USA

001 208 336 4900

CO2 HC NH3 H2O AIR

Danfoss
www.danfoss.us

Component Supplier

Heating - Industrial & Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Refrigeration - Transport
Air Conditioning - Stationary

11655 Crossroads Circle, Baltimore
21220 Maryland, USA

001 410 931 8250

CO2 HC NH3 H2O AIR

DC Engineering
www.dcengineering.net

Engineering / Contractor

Heating - Residential & Building
Heating - Industrial & Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Stationary

123 W Spruce St, Missoula
59802 Montana, USA

001 406 829 8828

CO2 HC NH3 H2O AIR

Diversified CPC
www.diversifiedcpc.com

Component Supplier

Refrigeration - Industrial

24338 W Durkee Road, Channahon
60410 Illinois, USA

001 815 424 2000

CO2 HC NH3 H2O AIR

Diversified Heat Transfer, Inc.
www.dhtnet.com

Component Supplier

Refrigeration - Industrial

439 Main Road, Route 202, Towaco
'07082 New Jersey, USA

001 800 221 1522

CO2 HC NH3 H2O AIR

Doucette
www.heatexchangers.doucetteindustries.com

Component Supplier

Refrigeration - Industrial

20 Leigh Drive, York
17406-8474 Pennsylvania, USA

001 717 845 8746

CO2 HC NH3 H2O AIR

Dwyer Engineering
www.dwyer.com

Engineering / Contractor

Refrigeration - Commercial

552 Fort Evans Road, NE, Suite 200, Leesburg
20176 Virginia, USA

001 703 777 5988

ebm-papst Inc.
www.ebmpapst.us

Component Supplier

Refrigeration - Domestic
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Industrial & Commercial

100 Hyde Road, P.O. Box 4009, Farmington
'06034 Connecticut, USA

001 860 674 1515

echogen power systems llc
www.echogen.com

System Manufacturer

Heating - Industrial & Commercial
Refrigeration - Industrial

365 Water Street, Akron
44308 Ohio, USA

001 234 542 4379

ecoFreeez
www.ecofreeez.com

Refrigerant Supplier

57 Pearl St, Brooklyn
11201-1146 New York, USA

001 347 442 9400

EcoThermics Corporation
www.ecothermics.com

Component Supplier

Heating - Industrial & Commercial
Air Conditioning - Industrial & Commercial

801 W. Main, Peoria
61606-1877 Illinois, USA

001 309 495 7320

Embraco North America (ENA)
www.embraco.com

Component Supplier

Refrigeration - Commercial

2800 Vista Ridge Drive NE, Suwanee
30024-3510 Georgia, USA

001 678 804 1337

Emerson Climate Technologies
www.emerson.com

System Manufacturer
Component Supplier

Heating - Industrial & Commercial
Refrigeration - Industrial

8000 West Florissant Avenue, P.O. Box 4100,
St Louis
63136 Missouri, USA

001 314 553 2000

ENREPS LLC
www.enreps.com

Engineering / Contractor

Refrigeration - Commercial

2432 W. Peoria Ave, Suite No 1166, Phoenix
85029 Arizona, USA

001 602 404 6535

Evapco
www.evapco.com

Component Supplier
System Manufacturer

Refrigeration - Industrial

P.O. Box 1300, Westminters
21158 Maryland, USA

001 410 756 2600

Extol

www.extolohio.com

Component Supplier

Refrigeration - Industrial

208 Republic Street, Norwalk
44857 Ohio, USA

001 419 668 2072

CO_2 HC NH_3 H_2O AIR

FES East LLC

www.fes-east.com

Component Supplier
Engineering / Contractor
Consultancy / Marketing

Refrigeration - Commercial
Refrigeration - Industrial

343 Pinnacle Drive, Lake Hopatcong
07849 New Jersey, USA

001 973 663 2636

CO_2 HC NH_3 H_2O AIR

Flowserve Pac-Seal

www.flowserve.com

Manufacturer
Supplier

Heating - Residential & Building
Heating - Industrial & Commercial
Refrigeration - Domestic
Refrigeration - Commercial
Refrigeration - Industrial
Refrigeration - Transport
Air Conditioning - Stationary
Air Conditioning - Mobile

5215 N. O'Connor Blvd., Suite 2300, Irving
75039 Texas, USA

001 972 443 6500

CO_2 HC NH_3 H_2O AIR

FreshArc, LLC

www.fresharc.com

System Manufacturer
Engineering / Contractor
Consultancy / Marketing

Refrigeration - Industrial

4021 Vernon Ave. S, St. Louis Park
55416 Minnesota, USA

001 952 270 8321

CO_2 HC NH_3 H_2O AIR

Freudenberg

www.fst.com/

Component Supplier

Air Conditioning - Mobile

1275 Archer Drive, Troy
45372 USA

CO_2 HC NH_3 H_2O AIR

FUCHS Lubricants Co.

www.fuchs.com

Refrigeration - Industrial

17050 Lathrop Avenue, Harvey
60426 Illinois, USA

001 708 333 8900

CO_2 HC NH_3 H_2O AIR

Galileo TP
www.galileotp.com

End of line solutions

Heating - Residential
Refrigeration - Domestic
Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Transport
Air Conditioning - Residential
Air Conditioning - Mobile

31 Boland Court, Greenville
29615 South Carolina, USA

001 864 288 1025

Gartner Refrigeration & MFG, INC.
www.gartner-refrig.com

Engineering / Contractor
Training

Refrigeration - Industrial

13205 - 16th Avenue N., Plymouth
55441 Minnesota, USA

001 763 559 5880

GEA Refrigeration North America Inc.
www.gearefrigeration.com

System Manufacturer
Component Supplier

Heating - Residential & Building
Heating - Industrial & Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Industrial & Commercial

3475 Board Road, York
17406 Pennsylvania, USA

001 717 767 6411

Genemco
www.genemco.com

Consultancy / Marketing

Refrigeration - Industrial

4455 Carter Creek Pkwy., Byran
77802 Texas, USA

001 979 268 7447

General Electric
www.ge.com

System manufacturer

3135 Easton Turnpike, Fairfield
'06828 Connecticut, USA

001 203 373 2211

General Monitors, Inc.
www.gmitoxics.com

System Manufacturer

Refrigeration - Industrial

26776 Simpatica Circle
92630 California, USA

001 949 581 4464

General Refrigeration Company
www.generalrefrig.com

System Manufacturer

Refrigeration - Industrial

P.O. BOX 140, Delmar
19940 Delaware, USA

001 302 846 3073

Global Refrigeration Solutions, LLC

System Manufacturer
Engineering / Contractor

Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Industrial & Commercial

944 Prescott Blvd, Deltona
32738 Florida, USA

Greenway Solutions Co.
www.greenwaysolutionsco.com

Refrigerant Supplier

120 Bethpage Road, Suite 304, Hicksville
11801 New York, USA

001 516 942 7805

Grundfos Pumps Inc.
www.us.grundfos.com

Component Supplier

Heating - Residential
Heating - Industrial & Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Residential
Air Conditioning - Industrial & Commercial

17100 West 118th Terrace, Olathe
66061 Kansas, USA

001 913 227 3400

CO_2 HC NH_3 H_2O AIR

Güntner U.S. LLC.
www.guntnerus.com

Component Supplier

Refrigeration - Light-Commercial
Refrigeration - Commercial

110 W. Hillcrest Blvd., Schaumburg
60195 Illinois, USA

001 847 781 0900

CO_2 HC NH_3 H_2O AIR

H.A. Phillips & Co.
www.haphillips.com

System Manufacturer

Refrigeration - Commercial
Refrigeration - Industrial

770 Enterprise Avenue, DeKalb
60115 Illinois, USA

001 630 377 0050

CO_2 HC NH_3 H_2O AIR

Hansen Technologies
www.hantech.com

Component Supplier

Refrigeration - Industrial

400 Quadrangle Drive, Suite F, Bolingbrook
60440 Illinois, USA

001 630 325 1565

CO_2 HC NH_3 H_2O AIR

Heatcraft Worldwide Refrigeration
www.heatcraftrpd.com

System manufacturer

Refrigeration - Commercial
Refrigeration - Industrial

2175 West Park Place Boulevard,
Stone Mountain, 30087 Georgia, USA

001 770 465 5600

CO_2 HC NH_3 H_2O AIR

Henderson Engineers, Inc.
http://www.hei-eng.com

Engineering / Contractor

Refrigeration - Commercial

8345 Lenexa Drive, Suite 300, Lenexa
66214 Kansas, USA

001 913 742 5000

CO_2 HC NH_3 H_2O AIR

Highland Refrigeration
www.highlandref.com

System Manufacturer
Engineering / Contractor

Refrigeration - Commercial
Refrigeration - Industrial
Refrigeration - Transport

4250 24th Avenue West, Seattle
98119 Washington, USA

001 206 213 0040

CO_2 HC NH_3 H_2O AIR

Hillphoenix
www.hillphoenix.com

System Manufacturer

Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial

1003 Sigman Road, Conyers
30013 Georgia, USA

001 770 285 3264

CO_2 HC NH_3 H_2O AIR

Hoshizaki America Inc.
www.hoshizakiamerica.com

Refrigeration - Light-Commercial

618 Hwy 74 South Peachtree City
30269 Georgia, USA

001 770 487 2331

CO_2 HC NH_3 H_2O AIR

Howe Corporation
www.howecorp.com

System Manufacturer

Refrigeration - Industrial

1650 N Elston Avenue, Chicago
60642-1585 Illinois,USA

001 773 235 0200

CO_2 HC NH_3 H_2O AIR

Hussmann
www.hussmann.com

System Manufacturer

Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Industrial & Commercial

12999 St. Charles Rock RD, Bridgeton
63044-2483 Missouri, USA

001 314 291 2000

CO_2 HC NH_3 H_2O AIR

Hydro Aluminium North Amercia
www.hydro.com

Component Supplier

Air Conditioning - Mobile

999 Corporate Blvd, Linthicum
21090-2254 Maryland, USA

001 888 935 5752

CO_2 HC NH_3 H_2O AIR

Hydro Cool
www.hydrocoolonline.com

Refrigerant supplier

James Hazel, Simpsonville
South Carolina, USA

001 864 299 9050

CO_2 HC NH_3 H_2O AIR

IMI Cornelius
www.imi-cornelius.com

System manufacturer

101 Regency Drive, Glendale Heights
Illinois, USA

001 630 539 6850

CO_2 HC NH_3 H_2O AIR

Ingersoll Rand
www.company.ingersollrand.com

System Manufacturer

Heating - Residential
Heating - Industrial & Commercial
Refrigeration - Transport
Air Conditioning - Residential
Air Conditioning - Industrial & Commercial
Air Conditioning - Mobile

800-E Beaty Street, Davidson
28036 Noth Carolina, USA

00 1704 655 4000

CO_2 HC NH_3 H_2O AIR

Innovative Refrigeration Systems Inc.
www.r717.net

System Manufacturer

Refrigeration - Industrial

373 Mt. Torrey Road, Lyndhurst
22952 Virginia, USA

001 540 941 1999

CO_2 HC NH_3 H_2O AIR

Insco Distributing
www.inscohvac.com

Component Supplier

Heating - Residential
Heating - Industrial & Commercial
Refrigeration - Domestic
Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Residential
Air Conditioning - Industrial & Commercial

12501 Network Blvd., San Antonio
78249 Texas, USA

001 210 690 8400

CO_2 HC NH_3 H_2O AIR

InterCool
www.intercoolusa.com

Engineering / Contractor

Heating - Industrial & Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Stationary

2426 Lacy lane, Carrollton
75006 Texas, USA

001 972 277 4505

CO_2 HC NH_3 H_2O AIR

IRS
www.industrialrefrigserv.com

Engineering / Contractor

Refrigeration - Industrial

P.O. Box 70019, Baltimore
21237 Maryland, USA

001 410 686 8900

Isotherm, Inc.
www.iso-therm.com

System Manufacturer

Heating - Industrial & Commercial
Refrigeration - Industrial
Refrigeration - Transport
Air Conditioning - Industrial & Commercial

7401 Commercial Blvd East, Arlington
76001 Texas, USA

001 817 472 9922

ITW Sexton
www.sextoncan.com

System Manufacturer

Refrigeration - Domestic
Air Conditioning - Mobile

3101 Sexton Rd, Decatur
35603-1453 Alabama, USA

001 256 355 5850

Jadeco, Inc
www.myjadeco.com

Engineering / Contractor

Refrigeration - Commercial
Air Conditioning - Industrial & Commercial

207B Kelsey Lane, Tampa
33619 Florida, USA

001 813 627 0243

Johnson Controls
www.johnsoncontrols.com

System Manufacturer

Heating - Industrial & Commercial
Refrigeration - Industrial
Air Conditioning - Industrial & Commercial

5757 N. Green Bay Ave. P.O. Box 591, Milwaukee
53201 Wisconsin, USA

001 414 524 1200

Johnson Controls/Frick
www.johnsoncontrols.com

System Manufacturer
Engineering / Contractor

Refrigeration - Industrial

100 Cumberland Valley Avenue
18268 Pennsylvania, USA

001 717 762 2121

K&P ENGINEERING

Engineering / Contractor

Refrigeration - Commercial

2322 Wilderness Way, Marietta
30066 Georgia, USA

001 678 860 2243

Lancer Corporation
www.lancercorp.com

System Manufacturer

Refrigeration - Light-Commercial

6655 Lancer Blvd, San Antonio
78219 Texas, USA

001 210 310 7000

Logix
www.logix-controls.com

Component supplier

Refrigeration - Industrial

10518 N.E. 68th Street, Suite 103, Kirkland
98033-7003 Washington, USA

001 425 828 4149

Luvata Grenada LLC
www.luvata.com

Component Supplier

Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Transport
Air Conditioning - Residential
Air Conditioning - Industrial & Commercial
Air Conditioning - Mobile

3984 US 51 South, Grenada
38901 Mississippi, USA

001 662 229 2000

CO_2 HC NH_3 H_2O AIR

M&M Refrigeration
www.mmrefrigeration.com

System manufacturer

Refrigeration - Industrial

412 Railroad Avenue, Post Office Box 449,
Federalsburg
21632 Maryland, USA

001 410 754 8005

CO_2 HC NH_3 H_2O AIR

Manitowoc Ice Inc.
www.manitowocice.com

System Manufacturer

Refrigeration - Commercial

2110 South 26th Street, Manitowoc
54220 Wisconsin, USA

001 920 682 0161

CO_2 HC NH_3 H_2O AIR

Manning Systems
www.manningsystems.com

Component supplier

Refrigeration - Industrial

23500 W. 105th Street, MD 400, Olathe
66061 Kansas, USA

001 913 712 5576

CO_2 HC NH_3 H_2O AIR

Mayekawa USA
www.mycomcanada.com

System Manufacturer

Heating - Industrial & Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Refrigeration - Transport
Air Conditioning - Industrial & Commercial

19475 Gramercy Place, Torrance
90501 California, USA

001 310 328 1362

CO_2 HC NH_3 H_2O AIR

McQuay
www.mcquay.comz

System Manufacturer

Refrigeration - Industrial

13600 Industrial Park Blvd., Minneapolis
55441 Minnesota, USA

001 763 553 5330

CO_2 HC NH_3 H_2O AIR

Mei Murray Equipment Inc.
www.murrayequipment.com

Engineering & Contracting

Refrigeration - Industrial

2515 Charleston Place, Fort Wayne
46808 Indiana, USA

001 260 484 0382

CO_2 HC NH_3 H_2O AIR

Metalfrio Solutions
www.metalfrio.com

System Manufacturer

Refrigeration - Light-Commercial
Refrigeration - Commercial

110 Enterprise Parkway, Boerne
78006 Texas, USA

001 830 755 2218

CO_2 HC NH_3 H_2O AIR

MicroGroove
www.microgroove.net

Component supplier

Refrigeration - Commercial
Refrigeration - Industrial

355 Lexington Ave. 15th Fl
10017 New York, USA

001 212 297 2100

CO_2 HC NH_3 H_2O AIR

Modine
www.modine.com

System Manufacturer
Component Supplier

Heating - Residential
Heating - Industrial & Commercial
Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Transport
Air Conditioning - Residential
Air Conditioning - Industrial & Commercial
Air Conditioning - Mobile

1500 DeKoven Ave, Racine
53403-2552 Wisconsin, USA

001 262 636 1200

Morrill Motors
www.morrillmotors.com

Component Supplier

Refrigeration - Commercial

229 S. Main Ave., Erwin
37650 Tennessee, USA

001 888 743 7001

Muller Industries
www.muellerindustries.com

Component Supplier

Refrigeration - Commercial
Refrigeration - Industrial

8285 Tournament Dr., Suite 150, Memphis
38125 Tennessee, USA

001 901 753 3200

Neelands Refrigeration
www.neelands.com

Engineering & Contracting
Refrigeration - Commercial

4131 Palladium Way, Burlington
L7M 0V9 Ontario, USA

001 905 332 4555

North Star
www.northstarice.com

System Manufacturer

Refrigeration - Industrial

8151 Occidental Avenue South, Seattle
98108 Washington, USA

001 206 763 7300

Northcutt
www.northcutt.org

Refrigerant Supplier

5055 N. Broadway, Wichita
Kansas, USA

001 316 838 1477

Novar
www.novar.com

Component Supplier

Refrigeration - Commercial

6060 Rockside Woods Blvd. Suite 400, Cleveland
44131 Ohio, USA

001 800 348 1235

Obrist
www.obrist-technologies.com

Engineering Contracting

12271 Honolulu Terrace, Whittier
90601 California, USA

001 248 808 0697

OZ Technology, Inc.
www.oztechnologyinc.com

Component Supplier

Refrigeration - Domestic
Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Refrigeration - Transport
Air Conditioning - Residential
Air Conditioning - Industrial & Commercial
Air Conditioning - Mobile

N. 10278 Church Road, Rathdrum
83858 Idaho, USA

001 208 687 7000

Pacific Sentry
www.pacificsentry.com

Component Supplier

Refrigeration - Industria

7126 180th Avenue NE, Suite C-106, Redmond
98052 Washington, USA

001 425 497 8494

CO_2 HC NH_3 H_2O AIR

Parker Hannifin
www.parker.com

Component Supplier

Refrigeration - Commercial
Refrigeration - Industrial

2445 S. 25th Ave., Braodview
60155 Illinois, USA

001 800 272 7537

CO_2 HC NH_3 H_2O AIR

Polar Refrigeration
www.polarservices.ca

Engineering / Contractor

Heating - Industrial & Commercial
Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Industrial & Commercial

402 21st Street W, Saskatoon
S7M 0W4 Saskatchewan, USA

001 866 652 3150

CO_2 HC NH_3 H_2O AIR

Power Engineers
www.powereng.com

Engineering / Contractor

Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Industrial & Commercial

3940 Glenbrook Drive, P.O. Box 1066, Hailey
83333 Idaho, USA

001 208 788 3456

CO_2 HC NH_3 H_2O AIR

R.M. Technologies
www.rmtech.net

Component supplier

Refrigeration - Industrial

3000 Atrium Way, Suite 243, Mount Laurel
8054 New Jersey, USA

001 800 775 4280

CO_2 HC NH_3 H_2O AIR

RAE Corporation
www.rae-corp.com

System Manufacturer

Refrigeration - Commercial
Air Conditioning - Industrial & Commercial

P.O. Box 1206, Pryor
74362 Oklahoma, USAS

001 918 825 7222

CO_2 HC NH_3 H_2O AIR

Recco
www.reccousa.com

System Manufacturer

Refrigeration - Industrial

22 Sixth Road, Woburn
‘01801 Massachusetts, USA

001 781 396 8780

CO_2 HC NH_3 H_2O AIR

Recold - SPX Cooling Technologies
www.spxcooling.com

System Manufacturer

Refrigeration - Industrial
Air Conditioning - Industrial & Commercial

7401 West 129 Street, Overland Park
66213 Kansas, USA

001 800 4Marley

CO_2 HC NH_3 H_2O AIR

Red Tek
www.redtek.ca

Refrigerant Supplier

PO Box 1114, Alcoa
37701 Tennessee, USA

001 888 676 9380

CO_2 HC NH_3 H_2O AIR

Resource Compliance
www.resourcecompliance.com

Engineering / Contractor

Consultancy / Marketing
Refrigeration - Industrial

P.O. Box 305, Dinuba
93618 California, USA

001 559 591 8898

CO_2 HC NH_3 H_2O AIR

Roberts Oxygen Company, Inc.
www.robertsoxygen.com

Refrigerant Supplier

Refrigeration - Commercial

15830 Redland Road, Rockville
20855 Maryland, USA

001 301 948 8100

CO_2 HC NH_3 H_2O AIR

Ryan Companies
www.ryancompanies.com

Engineering / Contractor

Refrigeration - Industrial

111 Shuman Boulevard, Suite 400, Naperville
60563-8678 Illinois, USA

001 630 328 1100

CO_2 HC NH_3 H_2O AIR

Sanden International USA
www.sanden.com

System Manufacturer

Heating - Residential
Heating - Industrial & Commercial
Refrigeration - Light-Commercial
Air Conditioning - Mobile

47772 Halyard Dr, Plymouth
48170 Michigan, USA

00 1 972 442 8400

CO_2 HC NH_3 H_2O AIR

SCHOTT North America, Inc.
www.schott.com

Component Supplier

Heating - Residential & Building
Heating - Industrial & Commercial
Refrigeration - Domestic
Refrigeration - Commercial
Refrigeration - Industrial

555 Taxter Road, Elmsford
10523 New York, USA

001 914 831 2200

CO_2 HC NH_3 H_2O AIR

Scotsman Ice Systems
www.scotsman-ice.com

Component Supplier

Refrigeration - Domestic
Refrigeration - Light-Commercial
Refrigeration - Commercial

775 Corporate Woods Pkwy, Vernon Hills
60061 Illinois, USA

001 847 215 4500

CO_2 HC NH_3 H_2O AIR

Sensata
www.sensata.com

Component Supplier

529 Pleasant Street, P.O. Box 2964, Attleboro
02703-0964 Massachusetts, USA

001 508 236 3800

CO_2 HC NH_3 H_2O AIR

Sentry Equipment Corp
www.sentry-equip.com

Component Supplier

Refrigeration - Industrial

966 Blue Ribbon Circle North, Oconomowoc
Wisconsin, USA

001 262 567 7256

CO_2 HC NH_3 H_2O AIR

Sherwood Vavle
www.sherwoodvalve.com

Component Supplier

2200 North Main St., Washington
15301 Pennsylvania, USA

001 724 225 8000

CO_2 HC NH_3 H_2O AIR

Shrieve Chemical Products
www.shrieve.com

Refrigeration - Domestic
Refrigeration - Industrial
Refrigeration - Transport
Refrigeration & Air conditioning lubricants
Air Conditioning - Stationary
Air Conditioning - Mobile

1755 Woodstead Court, Woodlands
75032 - 1448 Texas, USA

001 281 367 4226
001 281 367 0071

Solution Dynamics
www.sol-dyn.com

Engineering & Contracting

Refrigeration - Industrial

Kansas City
Missouri, USA

001 913 440 4912

Source Refrigeration
www.sourcerefrigeration.com

Engineering / Contractor

Refrigeration - Commercial

800 E. Orangethorpe Ave., Anaheim
92801 California, USA

001 714 578 2300

Southern Store Fixtures, Inc.
www.southerncasearts.com

Component Supplier

Refrigeration - Commercial

275 Drexel Rd, SE, Bessemer
35022 Alabama, USA

001 205 428 4800

Sporlan Parker
www.parker.com

Component Supplier

Heating - Residential
Heating - Industrial & Commercial
Refrigeration - Domestic
Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Refrigeration - Transport
Air Conditioning - Residential
Air Conditioning - Industrial & Commercial
Air Conditioning - Mobile

206 Lange Drive, Washington
63090 Missouri, USA

SPX Flow Technology Copenhagen A/S
www.spx.com

System Manufacturer
Component Supplier

Refrigeration - Industrial

13515 Ballantyne Corporate Place, Charlotte
28277 Noth Carolina, USA

Standard Xchange
www.standard-xchange.com

Component supplier

Refrigeration - Industrial

175 Standard Parkway, Cheektowaga
14227 New York, USA

001 800 281 4111

Steinmetz & Assoc, Inc.
www.marksteinmetz.com

Consultancy / Marketing

Refrigeration - Domestic
Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Residential
Air Conditioning - Industrial & Commercial

PO Box 6045, Lakeland
33807 Florida, USA

001 863 644 0333

Stellar
www.stellar.net

Engineering & Contracting

Refrigeration - Industrial

2900 Hartley Road, Jacksonville
32257 Florida, USA

001 904 260 2900

Stone Mountain Technologies
www.stonemtntechnologies.com

System Manufacturer

Refrigeration - Industrial

720 Watauga Avenue, Erwin
37650 Tennessee, USA

001 423 735 7400

CO_2 HC NH_3 H_2O AIR

Summit Appliance
www.summitappliance.com

System Manufacturer

770 Garrison Ave, Bronx
10474 New York, USA

001 718 893 3900

CO_2 HC NH_3 H_2O AIR

SWEP North America Inc.
www.swep.net

Component Supplier

Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Refrigeration - Transport

P.O. Box 11, Edgefield
29824 South Carolina, USA

001 464 184 004 00

CO_2 HC NH_3 H_2O AIR

Techmark International
www.techmark-intl.com

Component Supplier

Heating - Residential & Building
Heating - Industrial & Commercial
Refrigeration - Domestic
Refrigeration - Commercial
Refrigeration - Industrial
Refrigeration - Transport
Air Conditioning - Stationary
Air Conditioning - Mobile

11152 Westheimer Rd No 934, Houston
77042 Texas, USA

001 713 396 2260

CO_2 HC NH_3 H_2O AIR

Tecumseh
www.tecumseh.com

Component Supplier

Refrigeration - Commercial

1136 Oak Valley Dr, Ann Arbor
48108 Michigan, USA

001 734 585 9500

CO_2 HC NH_3 H_2O AIR

Teknotherm
www.teknotherm-inc.com

Component Supplier

Refrigeration - Industrial
Refrigeration - Transport

3941 Leary Way NW, Seattle
98127 Washington, USA

001 206 632 7883

CO_2 HC NH_3 H_2O AIR

Tempest
www.tempest-eng.com

System Manufacturer

Refrigeration - Industrial

8510 Bessemer Avenue, Cleveland
44127 Ohio, USA

001 216 883 6500

CO_2 HC NH_3 H_2O AIR

Temprite Company
www.temprite.com

Component Supplier

Refrigeration - Domestic
Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Refrigeration - Transport

1555 W. Hawthorne Lane, West Chicago
60185 Illinois, USA

001 630 293 5910

CO_2 HC NH_3 H_2O AIR

Thar Energy LLC
www.thargeo.com

System Manufacturer
Component Supplier
Engineering / Contractor

Heating - Industrial & Commercial
Air Conditioning - Industrial & Commercial

150 Gamma Drive, Pittsburgh
15238 Pennsylvania, USA

001 412 963 6500

CO_2 HC NH_3 H_2O AIR

The Brewer-Garrett Company
www.brewer-garrett.com

Engineering & Contracting

Refrigeration - Industrial

6800 Eastland Road, Middleberg Heights
44130 Ohio, USA

001 440 243 3535

CO_2 HC **NH_3** H_2O AIR

Thermal Transfer Systems, INC
www.thermaltransfersystems.com

System Manufacturer

Refrigeration - Industrial

P.O. Box 795096, Dallas
75379-5096 Texas, USA

001 972 242 9600

CO_2 HC **NH_3** H_2O AIR

Thermo Scientific
www.thermoscientific.com

System manufacturer

Refrigeration - Light-Commercial

81 Wyman Street, Waltham
'02454 Massachusetts, USA

001 781 622 1000

CO_2 **HC** NH_3 H_2O AIR

Traulsen
www.traulsen.com

System Manufacturer

Refrigeration - Light-Commercial
Refrigeration - Commercial

4401 Blue Mound Road, Fort Worth
76106 Texas, USA

001 800 825 8220

CO_2 **HC** NH_3 H_2O AIR

True Manufacturing Co
www.truemfg.com

System Manufacturer

Refrigeration - Domestic
Refrigeration - Light-Commercial
Refrigeration - Commercial

2001 East Terra Lane, O'Fallon
63366-4434 Missouri, USA

001 636 240 2400

CO_2 **HC** NH_3 H_2O AIR

True Temp
www.truetemprefrig.com

Component Supplier
Engineering / Contractor

Refrigeration - Commercial
Refrigeration - Industrial

13331 McCauley Cres., Maple Ridge B.C.
V4R 2V2 British Columbia, USA

001 604 760 4383

CO_2 HC **NH_3** H_2O AIR

Turbotec
www.turbotecproducts.com

Component Supplier

Refrigeration - Industrial

651 Day Hill Road, Windsor
6095 Connecticut, USA

001 860 731 4200

CO_2 HC **NH_3** H_2O AIR

United States Cold Storage
www.uscoldstorage.com

System Manufacturer

Refrigeration - Industrial

Four Echelon Plaza, 201 Laurel Road, Suite 400,
Voorhees
'08043 New Jersey, USA

001 856 354 8181

CO_2 HC **NH_3** H_2O AIR

Vaillant Group
www.vaillant.com

System Manufacturer
Engineering / Contractor
Consultancy / Marketing
Training / Research

Heating - Residential
Heating - Industrial & Commercial
Refrigeration - Domestic
Air Conditioning - Residential

New Jersey, USA

001 856 786 2000

CO_2 **HC** NH_3 **H_2O** AIR

Verisae
www.verisae.com/

Component Supplier

Refrigeration - Commercial

100 North Sixth Street, Suite 710A, Minneapolis
55403 Minnesota, USA

001 612 455 2300

CO_2 HC NH_3 H_2O AIR

VTech Process Equipment
www.vtechonline.com

System Manufacturer

P.O. Box 2931, Alharetta
30023 Georgia, USA

001 678 691 4935

CO_2 HC NH_3 H_2O AIR

Wagner-Meinert, Inc.
www.wagnermeinert.com

Engineering / Contractor
Training / Research

Refrigeration - Industrial

7617 Freedom Way, Fort Wayne
46818 Indiana, USA

001 260 489 7555

CO_2 HC NH_3 H_2O AIR

WIKA Instrument
www.wika.us

Component Supplier

Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Industrial & Commercial
Air Conditioning - Mobile

1000 Wiegand Blvd, Lawrenceville
30043 Georgia, USA

001 770 513 8200

CO_2 HC NH_3 H_2O AIR

Witt
www.htpgusa.com

System Manufacturer

Refrigeration - Industrial

USA

001 256 259 7400

CO_2 HC NH_3 H_2O AIR

York - Johnson Controls Unitary Products
www.york.com/products

Component Supplier

Refrigeration - Industrial

5005 York Drive, Norman
73069 Oklahoma, USA

001 717 762 2121

CO_2 HC NH_3 H_2O AIR

Zero Zone
www.zero-zone.com

System Manufacturer

Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial

110 N Oakridge Dr, North Prairie
53153-9792 Wisconsin, USA

001 262 392 6400

CO_2 HC NH_3 H_2O AIR

END USERS

CANADA

Sobeys
www.sobeys.com

End-User

Refrigeration - Commercial

115 King Street, Stellarton
B0K 1S0 Nova Scotia, Canada

001 902 752 8371

CO_2 HC NH_3 H_2O AIR

USA

Ahold USA
www.ahold.com

End-User

Refrigeration - Commercial

1149 Harrisburg Pike, Carlisle
17013 Pennsylvania, USA

001 717 249 4000

CO_2 HC NH_3 H_2O AIR

Ben & Jerry's
www.bendjeery.com

End-User

Refrigeration - Light-Commercial

30 Community Drive, South Burlington
05403-6828 Vermont, USA

001 802 846 1500

CO_2 HC NH_3 H_2O AIR

The Coca-Cola Company
www.coca-colacompany.com

End-User

Refrigeration - Commercial

1 Coca-Cola Plaza, Atlanta
30313 Georgia, USA

001 800 438 2653

CO_2 HC NH_3 H_2O AIR

Coleman Natural Foods
www.colemannatural.com

End-User

Heating - Industrial & Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Refrigeration - Transport
Air Conditioning - Industrial & Commercial

1155 Candler Road, Gainesville
30507 Georgia, USA

CO_2 HC NH_3 H_2O AIR

DeCA
www.commissaries.com

End-User

Heating - Industrial & Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Industrial & Commercial

2250 Foulois Street Suite 2, Lackland AFB
78236-1039 Texas, USA

001 210 671 2837

CO_2 HC NH_3 H_2O AIR

Delhaize America
www.delhaizegroup.com
www.foodlion.com
www.shopbloom.com
www.bottomdollarfood.com

End-User

Heating - Industrial & Commercial
Refrigeration - Commercial
Refrigeration - Transport
Air Conditioning - Industrial & Commercial

P.O. Box 1330, 2110 Executive Drive, Salisbury
28145-1330 Noth Carolina, USA

001 704 633 82 50

CO_2 HC NH_3 H_2O AIR

Fresh & Easy Neighborhood Market
www.freshandeasy.com

End-User

Heating - Industrial & Commercial
Refrigeration - Commercial
Air Conditioning - Industrial & Commercial

2120 Park Place Suite 200, El Segundo
90630 California, USA

001 310 341 1200

CO_2 HC NH_3 H_2O AIR

Maplehurst Bakeries LLC
www.maplehurstbakeries.com

End-User

Refrigeration - Industrial
Air Conditioning - Industrial & Commercial

50 Maplehurst Dr., Brownsburg
46112 Indiana, USA

001 317 858 9000

CO_2 HC NH_3 H_2O AIR

McDonald's
www.mcdonalds.com

End-User

Refrigeration - Industrial

2111 McDonald's Dr., Oak Brook
60523 Illinois, USA

001 800 244 6227

CO_2 HC NH_3 H_2O AIR

Nestlé
www.nestleusa.com

End-User

Refrigeration - Industrial

00 N. Brand Boulevard Glendale
91203 California, USA

001-800-225-2270

CO_2 HC NH_3 H_2O AIR

PepsiCo
www.pepsico.com

End-User

Refrigeration - Commercial

Frito-Lay , PO Box 660634, Dallas
75266-0634 Texas, USA

001 800 352 4477

CO_2 HC NH_3 H_2O AIR

Red Bull
www.redbullusa.com

End-User

Refrigeration - Light-Commercial

1740 Stewart St.
90404 California, USA

001 310 393 4647

CO_2 HC NH_3 H_2O AIR

Roche
www.gene.com

End-User

Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Industrial & Commercial

1 DNA Way, South San Francisco
94080 California, USA

001 650 225 1000

CO_2 HC NH_3 H_2O AIR

Roche Diagnostics
www.roche-diagnostics.us

End-User

Refrigeration - Industrial

9115 Hague Road, Indianapolis
46256 Indiana, USA

001 317 521 2000

CO_2 HC NH_3 H_2O AIR

SUPERVALU
www.supervalu.com

End-User

Heating - Industrial & Commercial
Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Industrial & Commercial

7075 Flying Cloud, Eden Prairie
55344 Minnesota, USA

001 952 828 4000

CO_2 HC NH_3 H_2O AIR

Target
www.target.com

End-User

Refrigeration - Commercial

CO_2 HC NH_3 H_2O AIR

Unilever
www.unilever.com

End-User

Refrigeration - Light-Commercial
Refrigeration - Industrial

800 Sylvan Avenue, Englewood Cliffs
07632 New Jersey, USA

001 201 894 7760

CO_2 HC NH_3 H_2O AIR

Walmart Stores, Inc
www.corporate.walmart.com

End-User

Heating - Industrial & Commercial
Refrigeration - Commercial
Air Conditioning - Industrial & Commercial

702 SW 8th Street, Bentonville
72716-8611 Arkansas, USA

001 479 273 4000

CO_2 HC NH_3 H_2O AIR

Wegmans
www.wegmans.com

End-User

Refrigeration - Commercial

1500 Brooks Avenue, PO Box 30844, Rochester
4603-0844 New York, USA

CO_2 HC NH_3 H_2O AIR

Whole Foods
www.wholefoodsmarket.com

End-User

Refrigeration - Commercial

550 Bowie Street, Austin
78703-4644 Texas, USA

001 512 477 4455

CO_2 HC NH_3 H_2O AIR

INTERNATIONAL HVAC&R ASSOCIATIONS & NGOS

Consumer Goods Forum

www.theconsumergoodsforum.com/

Association/Foundation

Refrigeration - Light-Commercial
Refrigeration - Commercial

22/24 rue du Gouverneur Général Eboué,
Issy-les-Moulineaux, 92130 France

0033 1 82 00 95 95

CO_2 HC NH_3 H_2O AIR

Greenpeace

www.greenpeace.org/

NGO

Heating - Residential
Heating - Industrial & Commercial
Refrigeration - Domestic
Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Refrigeration - Transport
Air Conditioning - Residential
Air Conditioning - Industrial & Commercial
Air Conditioning - Mobile

Ottho Heldringstraat 5, Amsterdam
1066 AZ The Netherlands

0031 207182000

CO_2 HC NH_3 H_2O AIR

ASHRAE

www.ashrae.org

Association/Foundation

Heating - Residential
Heating - Industrial & Commercial
Refrigeration - Domestic
Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Refrigeration - Transport
Air Conditioning - Residential
Air Conditioning - Industrial & Commercial
Air Conditioning - Mobile

1791 Tullie Circle, Atlanta
30329 Georgia, USA

00 1404 636 8400

CO_2 HC NH_3 H_2O AIR

Global Cold Chain Alliance

www.gcca.org/

Association/Foundation

Refrigeration - Industrial

1500 King Street Suite 201, Alexandria
22314-2730 Virginia, USA

001 703 373 4300

CO_2 HC NH_3 H_2O AIR

International Institute of Ammonia Refrigeration (IIAR)

www.iiar.org/

Association/Foundation

Heating - Residential
Heating - Industrial & Commercial
Refrigeration - Domestic
Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Refrigeration - Transport
Air Conditioning - Residential
Air Conditioning - Industrial & Commercial
Air Conditioning - Mobile

1001 N. Fairfax Street, Suite 503, Alexandria
22314 Virginia, USA

001 703.312.4200

CO_2 HC NH_3 H_2O AIR

International Institute of Refrigeration (IIR)

www.iifiir.org/

Association/Foundation

Heating - Residential
Heating - Industrial & Commercial
Refrigeration - Domestic
Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Refrigeration - Transport
Air Conditioning - Residential
Air Conditioning - Industrial & Commercial
Air Conditioning - Mobile

CO_2 HC NH_3 H_2O AIR

CANADA

Heating Refrigeration & Air Conditioning Institute of Canada (HRAI)

www.hrai.ca/

Association/Foundation

Heating - Residential
Heating - Industrial & Commercial
Refrigeration - Domestic
Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Refrigeration - Transport
Air Conditioning - Residential
Air Conditioning - Industrial & Commercial
Air Conditioning - Mobile

2800 Skymark Avenue, Building 1, Suite 201, Mississauga
L4W 5A6 Ontario, Canada

001 905-602-4700

Humber College

www.humber.ca

Training / Research

Heating - Residential
Heating - Industrial & Commercial
Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Residential
Air Conditioning - Industrial & Commercial

205 Humber College Blvd, Toronto
M9W 5L7 Ontario, Canada

001 416 675 3111

Manitoba Ozone Protection Industry Association (MOPIA)

www.mopia.ca

Association / Foundation

1082 Main Street, Winnipeg
R2W 5J3 Manitoba, Canada

001 204 338 2222

Mechanical Contractors Association of Canada (MCAC)

www.mcac.ca/

Association/Foundation

Heating - Residential
Refrigeration - Domestic
Air Conditioning - Residential

#601-280 Albert Street, Ottawa
K1P 5G8 Ontario, Canada

001 613 232-0492

Natural Resources Canada

www.nrcan.gc.ca

Training / Research

Heating - Industrial & Commercial
Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Residential
Air Conditioning - Industrial & Commercial

1615 Boul. Lionel-Boulet, Varennes
J3X 2H5 Québec, Canada

001 450 652 4621

Refrigeration Service Engineers Society (RSES) Canada

www.rsescanada.com

Association

Heating - Residential
Heating - Industrial & Commercial
Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Residential
Air Conditioning - Industrial & Commercial

PO Box 3, Station B, Etobicoke
M9W 5K9 Ontario, Canada

MEXICO

Associacion National de Distribuidores de la Industria de la Refrigeracion y Aire Acondicionado (ANDIRA)

www.andira.org.mx

Association/Foundation

0052 55 1253 9815

CO_2 HC NH_3 H_2O AIR

Asociacion Nacional de contratistas, Instaladores y Tecnicos de la refrigeracion, aire acondicionado, Calefaccion y Ventilacion, A.C. (Ancitracv)

www.ancitracv.com

Av. Playa Revolcadero 222, Col. Reforma
Iztaccíhuatl Norte 08810 Del. Iztacalco
México, D.F., Mexico

0052 55 5741 5462

CO_2 HC NH_3 H_2O AIR

Associacion National de Fabricantes para la Industria de la Refrigeracion (ANFIR)

www.anfir.mx

Association/Foundation

Refrigeration - Commercial
Refrigeration - Industrial

Insurgentes Sur No. 686 – 1001, Col. Del Valle
03100 México D.F., Mexico

0052 55 5536 6217

CO_2 HC NH_3 H_2O AIR

University of Guanajuato

www.ugto.mx

Training / Research

Refrigeration - Domestic
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Residential
Air Conditioning - Industrial & Commercial
Air Conditioning - Mobile

Lascurain de Retana 5, Centro
36000 Guanajuato, Mexico

0052 473 732 0006

CO_2 HC NH_3 H_2O AIR

USA

Air Conditoning Contractors of America (ACCA)

www.acca.org

Association/Foundation

2800 Shirlington Road, Suite 300, Arlington
22206 Virginia, USA

001 703 575 4477

CO_2 HC NH_3 H_2O AIR

Air-Conditioning, Heating, and Refrigeration Institute (AHRI)

www.ahrinet.org

Association/Foundation

Heating - Residential
Heating - Industrial & Commercial
Refrigeration - Domestic
Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Refrigeration - Transport
Air Conditioning - Residential
Air Conditioning - Industrial & Commercial
Air Conditioning - Mobile

2111 Wilson Blvd, Suite 500, Arlington
22201 Virginia, USA

001 703-524-8800

CO_2 HC NH_3 H_2O AIR

Ammonia Refrigeration Foundation

www.nh3foundation.org

Association/Foundation

Refrigeration - Industrial

1001 North Fairfax Street, Suite 503
22314 Virginia, USA

001 703 312 4200

CO_2 HC NH_3 H_2O AIR

Associated Grocers Inc.

www.agbr.com

End-User

Heating - Industrial & Commercial
Refrigeration - Commercial
Refrigeration - Industrial

8600 Anselmo Lane, Baton Rouge
70810 Louisiana, USA

CO_2 HC NH_3 H_2O AIR

Cold Systems

www.coldsystemsllc.com

Training / Research
Association/Foundation

Refrigeration - Industrial

762 Highlander Point Drive No 289, Floyds Knobs
47119 Indiana, USA

001 608 219 4495

CO_2 HC NH_3 H_2O AIR

EOS Climate

www.eosclimate.com

Association/Foundation

55 Hawthorne Street, Suite 610, San Francisco
94105 California, USA

001 800-764-8093

CO_2 HC NH_3 H_2O AIR

Garden City Ammonia Program (GCAP)

www.ammoniatraining.com

Training / Research

Heating - Residential & Building
Heating - Industrial & Commercial
Refrigeration - Commercial
Refrigeration - Industrial

2405 East Fulton Plaza, Garden City
67846 Kansas, USA

001 620 271 0037

GreenChill Partnership

www.epa.gov/greenchill

Refrigeration - Commercial

1200 Pennsylvania Ave NW (MC 6205J),
Washington, 20460 Washington DC, USA

001 202 272 0167

Heating, Air-conditioning and Refrigeration Distributors International (HARDI)

www.hardinet.org

Association/Foundation

3455 Mill Run Drive - Suite 820, Columbus
43026 Ohio, USA

001 614 345 4328

HSB I&I

www.hsb.com

Training / Research

Heating - Industrial & Commercial
Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Industrial & Commercial

1 State Street, Hartford
06102 Connecticut, USA

001 860 722 1866

Ionic Research Technologies LLC

www.ionicresearchtechnologies.com

Training / Research

Heating - Residential
Refrigeration - Light-Commercial

1400 East Angela Blvd., Suite 328, South Bend
46530 Indiana, USA

Mechanical Contractors Association of America (MCAA)

www.mcaa.org

Association/Foundation

1385 Piccard Drive, Rockville
20850 USA

001 301 869 5800

National Renewable Energy Laboratory (NREL)

www.nrel.gov

Association / Foundation

Heating - Residential
Heating - Industrial & Commercial
Refrigeration - Domestic
Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Residential
Air Conditioning - Industrial & Commercial

15013 Denver West Parkway, Golden
80401 Colorado, USA

001 303 275 3000

Oak Ridge National Laboratory

www.ornl.gov

Engineering / Contractor
Consultancy / Marketing
Training / Research

Heating - Residential
Refrigeration - Domestic
Refrigeration - Commercial
Air Conditioning - Residential

PO Box 2008, Bldg 3147, MS-6070, Oak Ridge
37831-6070 Tennessee, USA

001 865 576 7658

Preston Refrigeration

www.prestonrefrigeration.com

Training / Research

Refrigeration - Industrial

3200 Fiberglass Road, Kansas City
66115 Kansas, USA

001 913 621 1813

Refrigeration Service Engineers Society (RSES)

www.rses.org

Training

Refrigeration - Industria

1911 Rohlwing Road, Suite A, Rolling Meadows
60008-1397 Illinois, USA

001 800 297 5660

CO_2 HC NH_3 H_2O AIR

Refrigerating Engineers & Technicians Association (RETA)

www.reta.com

Research

Refrigeration - Industria

PO BOX 1819, Salinas
93902 California, USA

001 831 455 8783

CO_2 HC NH_3 H_2O AIR

Selby Service and Consulting Inc

www.selbyservice.com

Training

Refrigeration - Industria

PO Box 1249, Katy
77492-0768 Texas, USA

001 832 928 0768

CO_2 HC NH_3 H_2O AIR

Sheet Metal and Air Conditioning Contractors' National Association (SMACNA)

www.smacna.org

Association/Foundation

Air Conditioning - Residential
Air Conditioning - Industrial & Commercial

4201 Lafayette Center Drive, Chantilly
20151-1219 Virginia, USA

001 703 803 2980

CO_2 HC NH_3 H_2O AIR

UANJ.org

www.uanj.org

Training / Research

Heating - Industrial & Commercial
Refrigeration - Domestic
Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Refrigeration - Transport
Air Conditioning - Industrial & Commercial

36 Second Street, Hillburn
10931-0805 New York, USA

CO_2 HC NH_3 H_2O AIR

University of Illinois at Urbana-Champaign

www.illinois.edu

Training / Research

Refrigeration - Domestic
Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Refrigeration - Transport
Air Conditioning - Residential
Air Conditioning - Industrial & Commercial
Air Conditioning - Mobile

1205 W. Green Street, Urbana
61801 Illinois, USA

001 217 333 1000

CO_2 HC NH_3 H_2O AIR

US Environmental Protection Agency (EPA)

www.epa.gov

Association/Foundation

Refrigeration - Domestic
Refrigeration - Light-Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Refrigeration - Transport
Air Conditioning - Residential
Air Conditioning - Industrial & Commercial
Air Conditioning - Mobile

1200 Pennsylvania Ave NW (MC 6205J), Washington
20460 Washington DC, USA

001 202 272 0167

CO_2 HC NH_3 H_2O AIR

ABOUT THE AUTHORS

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Head of Market Research

Nina holds a degree in Business Management and a post-graduate degree in Environmental Management from the University of London. After serving in a communications role for global energy supplier Norsk Hydro, she has, for the last 7 years, been working in the field of environmental technologies, where she has developed special expertise on natural refrigerants. Today, she is mostly active in business development for market intelligence and consultancy services, as well as special projects and publications. She has been drafting and supervising regional studies on behalf of UNEP's OzonAction branch, as well as served as project coordinator for various EU projects.

MARC CHASSEROT

Managing Director

Marc holds degrees (incl. two Masters) in Economics, Politics, and Marketing. He has studied at the London School of Economics, INSEAD Singapore, Sciences Po Paris, and the College of Europe. He has specialized in natural refrigerants since 2003. He is a member of the ASHRAE Refrigeration Committee. He founded the leading industry platforms R744.com, hydrocarbons21.com, and ammonia21.com. He is also the founder and Chairman of the international workshop series known as ATMOsphere.

JANAINA TOPLEY LIRA

Market Research Analyst

Janaina holds a Master's degree in Environmental Technology from Imperial College London and has a broad understanding of the environment arena, with specialist knowledge of climate change related issues. Prior to joining shecco, she worked in communications, research and policy analysis in the NGO sector. Now supporting shecco's market research department, Janaina provides analysis of HVAC&R markets for special projects and publications.

ALEXANDRA MARATOU

Senior Policy Analyst

Alexandra completed post-graduate studies in Environmental and Resource Economics at University College London, UK. Since then, environmental issues have been the drive and focus in her professional career, which, before joining shecco, involved her role as a research assistant at the Electricity Policy Research Group at the University of Cambridge, UK. At her current position in shecco, she leads the company's public affairs department, raising policy makers' awareness of the benefits of climate friendly natural refrigerant-based technologies.

HUITING JIA

Market Research Analyst

Huiting holds two Masters' degrees in Development Studies and International Relations from Groningen University, Netherlands and Uppsala University, Sweden. With a background in EU policy, politics, and the Chinese economy, Huiting currently works as part of shecco's Market Research team. Her expertise is in providing tailored analysis of key trends and developments, and assisting clients to optimize their strategy in target HVAC&R markets.

Unlock the market for climate friendly technologies

guide
shecco publications

shecco's market research department publishes an easy-to-access online reference series for the global market for natural refrigerants known as "GUIDEs", which include the following:

- Market outlook based on industry survey
- CO_2 supermarket maps
- End-user views and case studies

The GUIDE series includes editions on the European and North American market, and will soon be complemented with editions on China and Japan.

shecco's market research department offers:

- Tailor-made market studies depending on your budget and needs
- Multi-client market research for industry, trade, and NGOs
- News monitoring & continuous market tracking
- Policy audits & issue tracking
- Funding audits & grant project management
- Consultancy services, partner assessment, customer search

We provide quantitative and qualitative market research to ensure the most appropriate and cost effective methodologies are used for each project. Market research services include:

- Research design and set-up
- Online & telephone surveys, in-depth interviews
- Data processing & analysis
- SWOT analysis & trend forecasting

Whilst shecco's multidisciplinary team has a wealth of knowledge across the range of "green technologies", we have special access to a global network of industry and policy decision makers in the following areas:

- Natural refrigerants
- Heating, ventilation, air conditioning and refrigeration (HVAC&R)
- Electric Vehicles (four wheelers, scooters / bikes etc.)

For more information, contact:
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guide

shecco publications

Get in touch with us to learn how we can help you in gathering business intelligence, in getting your climate friendly technology faster to market, and in spreading your message among decision makers.

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