guide
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2012: NATURAL REFRIGERANTS MARKET GROWTH FOR EUROPE

GUIDE 2012: NATURAL REFRIGERANTS

MARKET GROWTH FOR EUROPE

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MARC CHASSEROT
Publisher and Managing Director of shecco

A SHORT MESSAGE

shecco has been working at the cutting edge of natural refrigerant technology for over a decade. We are asked every day for trends, examples and data. This is growing as the market potential for natural refrigerants rises around the world.

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

Today we go one step further by publishing the first in a series of free GUIDES to help HVAC&R stakeholders to better understand the potential of natural refrigerants. We've worked with leading companies in the field and engaged with hundreds of experts across Europe.

Happy reading

ABOUT THIS GUIDE

A SHORT OVERVIEW

"The function of leadership is to produce more leaders, not more followers." This has never been more true than at this very moment when bold steps need to be taken by the international business community to advance more sustainable production and consumption patterns. With pressure by rulemakers, business partners and consumers to push environmental issues up the agenda unlikely to subside anytime soon, companies are tasked to re-think established solutions and implement environmentally benign, yet economically sensible technologies to seize their individual "eco-advantage".

The use of refrigerants free of ozone-depleting and global warming characteristics in heating, refrigeration & air-conditioning will continue taking a central role in the debate about the "low-hanging fruits" of greenhouse gas emissions reductions at all levels – from international climate talks down to national strategic plans. It is no longer unthinkable to say CFCs, HCFCs and HFCs are not going to stand the test of time. Air, ammonia, carbon dioxide, water and the groups of hydrocarbons, on the other hand, stand ready as current and future solutions in residential refrigerators, commercial heat pumps, industrial waste energy recovery or global food logistics.

But while the environmental and technological benefits of these "natural refrigerants" are now being acknowledged by more and more business leaders, only few studies have heard the industry's voice on their economic prospects. This guide sets out to shed light on precisely this question: Where do natural refrigerants make most sense today and tomorrow, and what is impeding their success in the world and specifically in the European Union? It has listened to little less than 1,300 voices from the HVAC&R (Heating, Ventilation, Air-Conditioning & Refrigeration), industry responding to a global survey conducted between March to September 2011.

Chapter 1 - a User's Guide to Natural Refrigerants - briefly summarises the characteristics of ammonia, carbon dioxide and hydrocarbons, while trying to depict their use in four "ecosystems": Transport, City & Buildings, Industry & Special Applications, and The Food Chain. The chapter concludes with an outlook on the adoption potential of natural working fluids in different world regions.

Chapter 2 - will look at the European market situation today, by both analysing the technology potential, as well as the impact of European Union rules and standards on developing a prosperous market for natural working fluids. For the first time, an attempt is made to quantify one of the unfolding success stories in Europe: the use of CO_2 transcritical supermarket refrigeration systems. The chapter closes with case studies - evident examples of installations where natural refrigerants make sense both from a business and environmental perspective.

Chapter 3 - then takes a glance at success factors for ammonia, carbon dioxide and hydrocarbons in tomorrow's Europe. This chapter encompasses some of the GUIDE: 2012's core messages by drawing attention to existing barriers to the market uptake of natural refrigerants, their major strengths, and by presenting the European industry's expectations per industry sector as regards natural working fluids for the years 2012-2020. The GUIDE: 2012 concludes with a Directory listing of European-based companies and international organisations already active in natural refrigerants today, base largely on responses to an HVAC&R industry survey.

This guide puts forward evidence that there is a market for more sustainable refrigerant solutions, and that it is growing. But before industry, policy and consumers can inspire others to become leaders in adopting HFC-free refrigerants they need to know first where we stand today. I hope that this guide can help this process.

NINA BURHENNE
Head of Market Research
Editor & Lead Author

USER'S GUIDE TO NATURAL REFRIGERANTS

USER'S GUIDE TO NATURAL REFRIGERANTS

The "Natural Five" air, ammonia, carbon dioxide, hydrocarbons and water have distinct characteristics that make them viable options for a wide application range today and tomorrow. See a short overview of the most commonly used natural working fluids and their chemical, physical, technical and environmental properties, as well as existing challenges, on ...

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NATURAL REFRIGERANTS TODAY: AN ECOSYSTEM APPROACH

Carbon dioxide, ammonia and the group of hydrocarbons are valued as energy-efficient refrigerants and/or prospective options 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", and an indication of natural refrigerants' future potential, starting from ...

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NATURAL REFRIGERANTS TOMORROW: A GLOBAL VIEW

What is the overall adoption potential for ammonia, carbon dioxide and hydrocarbons in different world regions? A global industry survey has received around 1,300 views from manufacturers, suppliers, installers and end-users on the future of natural working fluids for the years to come. See why Europe will remain the leader in using HFC-free refrigerants – the answer on ...

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ABOUT NATURAL REFRIGERANTS

AN OVERVIEW

As a general separation, “natural refrigerants” are substances that exist naturally in the environment, whilst ”non-natural refrigerants” or “synthetic refrigerants” are man-made chemicals, not naturally occuring in the environment. The term “natural” refrigerants is sometimes disputed as one of not entirely precise nature - given that ammonia, carbon dioxide and hydrocarbons also pass an industrial purification and manufacturing process to be used as refrigerants. However, today a well-established distinction between substances whose chemical properties and safety aspects have been studied by mankind in their entirety, and those fluorinated gases - given their chemical complexity and comparatively short period of usage - whose confirmed and/or still unknown negative contribution to ozone depletion, global warming and ecological safety 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 optimised performance and safety properties (isobutane/propane; R441 etc.). Water and air are also used to a minor extent, such as in adsorption chillers and deep-freezing applications. Given their non-toxicity and non-flammability, in addition to their unbeatable environmental credential in combination with widest availability, these latter two have shifted again to the focus of R&D activities today. 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 colourless, odourless and is also heavier than air. With a Global Warming Potential = 1, CO_2 is the reference value for comparing a refrigerant’s direct impact on global warming. Carbon dioxide carries an A1 safety classification (the same as most fluorocarbon refrigerants), indicating that it has low toxicity and is non-flammable. CO_2 as a refrigerant is sourced from a number of production methods as a by-product. Whilst it is non-toxic if enough carbon dioxide builds up in an enclosed space it will begin to displace oxygen and can cause asphyxiation in anyone present over a certain period within the space. 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 usually 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 colourless 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-product or decomposition products with negative environmental impact. Sourced from a variety of sources, 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 has only 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 higher toxicity and lower flammability characteristics. 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 minimise risks for human health, particularly for ammonia installations in populated areas. They include using ammonia in conjunction with other refrigerants in order to reduce and isolate the ammonia charge, such as in secondary systems; using advanced safety equipment; deploying containment casings; ammonia absorption systems.

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

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

HYDROCARBONS (ODP=0; GWP<3)

With no ozone-depleting characteristics and ultra-low global warming impact, the group of hydrocarbons do not form any by-products or decomposition products in the atmosphere. HC refrigerants can be used either in systems designed specifically for their use, or as a replacement in a system designed for a fluorocarbon refrigerant, making them a cost-competitive solution including in 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, including lubricant compatibility, and address the issues associated with hydrocarbons' flammability. 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 as regards the quantities allowed in occupied spaces.

Hydrocarbon refrigerants are fully compatible with nearly 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).

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	17/03/11
Carbon dioxide	R744	CO_2	1	0	-56.6	31,1	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	- 194.5	-	-	-	28.97

THE LINDE GROUP

Linde

Natural refrigerants for a cleaner tomorrow.

Cool by nature.

We are committed to the responsible use of natural resources, the development of clean technologies and the replacement of harmful substances with eco-friendly alternatives. As a global leader in providing refrigerant gases and services, Linde is proud to support the introduction of natural refrigerants in many countries around the world.

Linde provides a range of high quality ammonia, carbon dioxide and hydrocarbon based natural refrigerants that meet the exacting purity requirements of air conditioning and refrigeration applications. Combined with extensive technical support we ensure responsible and safe usability.

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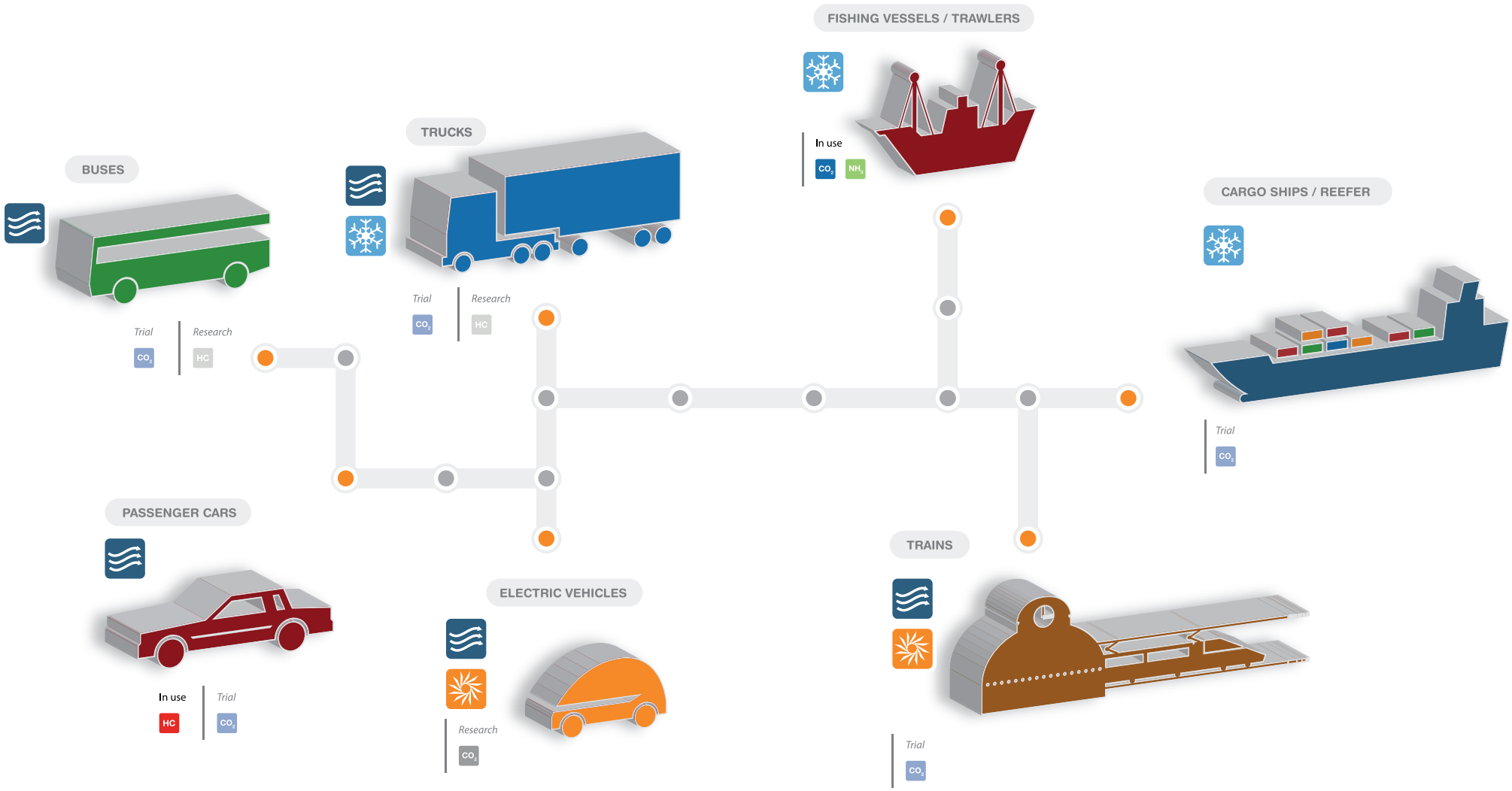
NATURAL REFRIGERANTS TODAY

AN ECOSYSTEM APPROACH

Natural refrigerants can be used in a variety of applications, covering the entire range of air-conditioning, refrigeration and heating systems. While excellent technical publications and information platforms (see GTZ 2008, TEAP 2010, UNEP 2011, UNEP HCFC Help Centre) have detailed the potential of natural refrigerants by system type, the approach selected here focuses on a non-exhaustive visual approach to presenting end-use applications of natural working fluids. The intention is to group representative types of buildings, facilities, installations and vehicles in 4 different "ecosystems" providing an easy-to-access overview to industry, policy and end-users that can demonstrate the current adoption potential ranging from existing market offerings ("In use"), to first demonstration projects ("Trial"), and ongoing research & development activities ("Research"). These charts will be expanded and updated in following publications, whenever new natural refrigerants-based solutions will have become available.

TRANSPORT APPLICATIONS



NH3 Ammonia | CO2 Carbon Dioxide | HC Hydrocarbons | Refrigeration | Heating | Air Conditioning

TRANSPORT APPLICATIONS

CARS & ELECTRIC VEHICLES

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 is the world's first to use hydrocarbons in its range of on/off road vehicles. Today, it is estimated that the share of hydrocarbons (HCs) 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 in secondary loop systems to ensure a safer use. Given their cost-effectiveness, HC systems constitute a promising market in developing countries, once training on installation and maintenance is prioritised. Moreover, with the adoption of flammable synthetic refrigerants in passenger cars, currently developed safety systems could accelerate the use of HCs. It should be noted that hydrocarbons are particularly suited to hot climates and in applications with limited space such as mobile air conditioning systems.

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. Whilst all components for the CO_2 system have been fully developed, the commercialisation in passenger cars has been delayed due to resistance by the automotive industry. Prototypes have been tested extensively, including in a German Federal Environment Agency (UBA) car. Of special interest for the future adoption of CO_2 MAC with combined heat pumping function could be the introduction of electric vehicles, where less waste heat from the motor can be used for heating the passenger compartment. New impetus for the use of carbon dioxide refrigerant might be expected within the next 5 years.

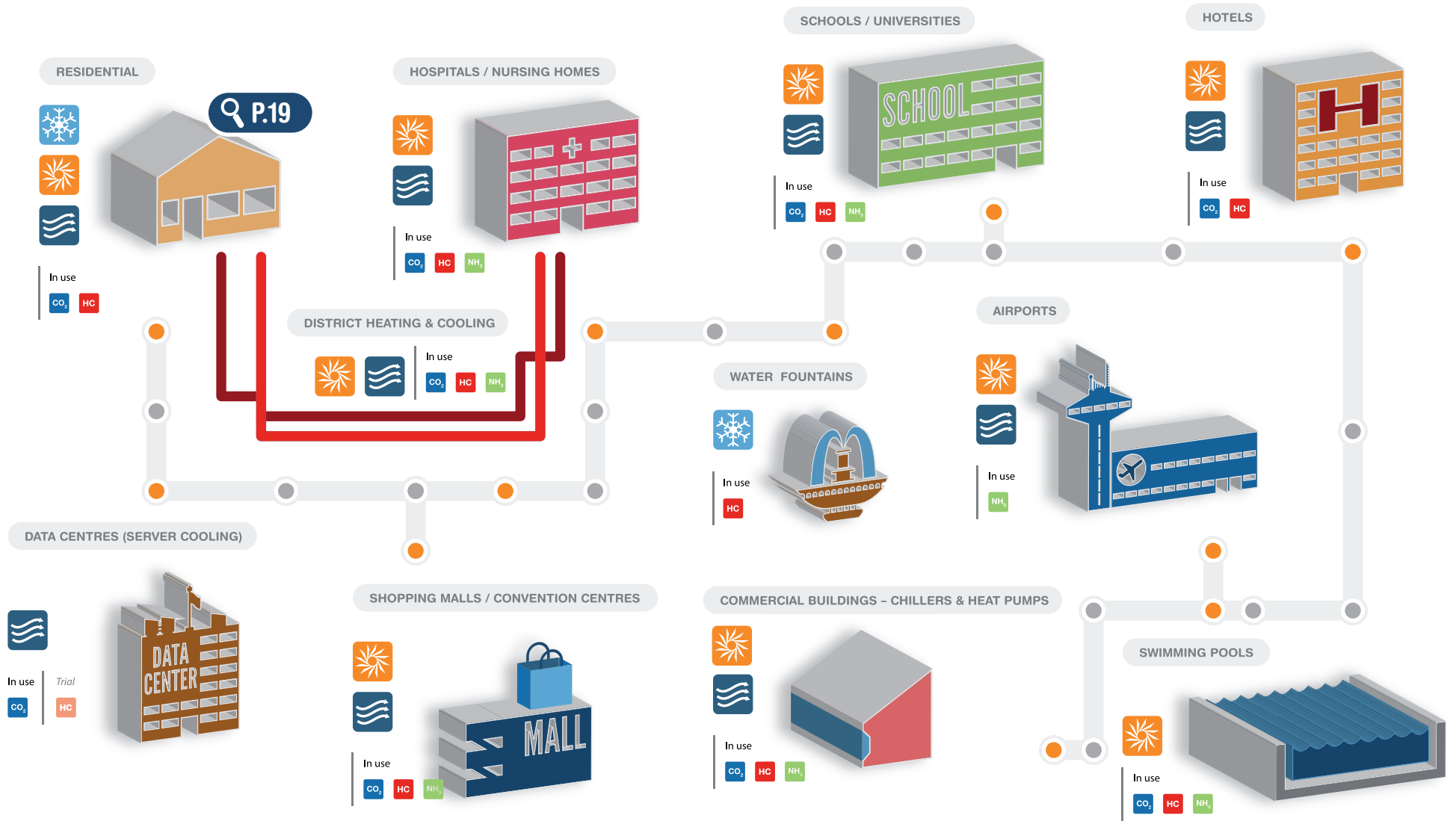
BUSES, TRUCKS & TRAINS

CO_2 / HC: So far, CO_2 MAC has been commercialised in around 30 buses – among them two hybrid electric buses and one with reversible operation for combined heating - that have covered more than 3.3 million km in Germany and Luxembourg. CO_2 systems for trains, which operate like a modern air-air heat pump, are also currently being tested in Germany, this time by the national train operator Deutsche Bahn. Highest future potential for air conditioning in larger vehicles is expected for CO_2 and hydrocarbons. The time scale for a broader commercialisation of CO_2 MAC in buses and trains is expected to be 3 years, largely depending on the (unlikely) enforcement of low-GWP requirements for the public transport sector, as well as overall signals sent by the automotive industry and commitment by individual public transport providers. The US Environmental Protection Agency sees CO_2 as the only viable long-term alternative for buses and trains. Leading system suppliers have announced product ranges with natural refrigerants for vans, trucks vand trailer equipment in the near future. CO_2 and HCs are also used in transport refrigeration (see page 22).

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 is expected to grow. Both ammonia and carbon dioxide, either alone or in combination and indirect systems for low-temperature applications, have been used in marine refrigeration equipment to refrigerate or freeze catch at sea. Together, their global market share is still estimated at below 5%. Most recently, CO_2 transcritical systems for container shipping were put to extensive life-testing with a world-leading cargo company to prove efficiency and reliability at all ambient temperatures around the world. The emissions savings potential could be substantial, given that 65% of all refrigerated transport is done via container shipping.

CITY & BUILDINGS



NH3 Ammonia | CO2 Carbon Dioxide | HC Hydrocarbons | Refrigeration | Heating | Air Conditioning

CITY & BUILDINGS

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

NH_3: Large ammonia chillers are now safely used in heating and cooling applications in populated areas, providing high efficiencies and reducing energy consumption. For example Terminal 5 at London's Heathrow Airport uses a central ammonia chilling plant to provide comfort heating and cooling for passengers and workers. The energy center for the London Olympics (2012) features ammonia chillers as part of the low carbon heating and cooling system that will cater for the needs across the site. Moreover, the Aquatics Center makes use of a separate NH_3 chillers. 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 for the cooling needs of its operating theatre, 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 to save 1560 tons CO_2/year.

HC: Also now used to provide comfort heating and cooling in public buildings are hydrocarbon chillers, which tend to have lower capital costs than ammonia chillers, as they do no need to use "industrial grade" steel components. They have proven safe to install in populated areas, in hospitals and even historical buildings. Prominent installations in the UK include a 600 kW air-cooled water chiller using R290 (propane) installed in the historic Church House Westminster Abbey in London, UK, whilst the UK Department of Transport have installed 3 hydrocarbon rooftop chillers on Great Minster House, central London. Arhus University Hospital Skejby, Denmark has installed R600a (isobutane) heat pumps and R290 (propane) chillers for comfort heating and cooling and hot water. One estimation amounts to a global market potential for HC chillers of $4 billion. 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), as is the case in Buntingsdale Infant Shool in the UK, where heat is extracted from the ground and upgraded to a useful temperature by an R290 (propane) heat pump unit.

CO_2: Hot water heat pumps using CO_2 are used primarily in Japan in public buildings, where for example a commercial size Eco Cute is installed in ASA Hospital in Hiroshima, providing 60% of the hot water demand. Such systems are, however, now starting to appear in other countries. In Ireland and the UK the Cúil Dídin Nursing Care Facility and Beechdale Manor Care home both use CO_2 heat pumps to provide all their hot water needs.

The name of the Eco Cute comes from the Japanese phrase Shizen Reibai Hīto Ponpu Kyūtō-ki, which literally means "natural refrigerant heat pump water heater". Eco is a contraction of either Ecology or Economical and Cute is a near homonym to kyūtō ; literally "supply hot water."

COMMERCIAL BUILDINGS: AIR-CONDITIONING & HEATING

NH_3 / HC: In the last decade ammonia and hydrocarbon chillers have started to gain acceptance for the provision of comfort air conditioning (A/C) and heating for universities, hospitals, hotels, office buildings, convention centers, and airports. In Asia, several hydrocarbon chiller conversions have been undertaken in the Philippines, in Gaisano Country Mall, Legenda Hotel and the Mandarin restaurant. The Jusco Melaka shopping centre in Malaysia has also converted its cooling system to hydrocarbons, installing 50 25-50 kW water-cooled packages and 100 split systems. In Indonesia, the Grand Melia Hotel, Jakarta, retrofitted six chillers with R290 (propane) to provide air conditioning. Unfortunately, due to a lack of trained technicians this retrofit was recently re-retrofitted back to R22. In addition hydrocarbon ground source heat and exhaust air heat pumps have been developed in Europe, where they have been installed to provide heating to schools and residential buildings. These can also be installed in commercial buildings.

CO_2: In South-West Japan a business hotel in Tottori uses a commercial Eco Cute heat pump water heater, whilst O'Donovan's Hotel in Ireland has also invested in a CO_2 heat pump water heater after seeking an efficient and renewable alternative to their hybrid solar-oil fired boiler system.

DATA CENTRE COOLING

CO_2 / HC: Data centres that house computer systems and components such as telecommunications and storage systems need to have rigorous temperature and humidity control to maintain 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, has been used as the refrigerant

for data centre air conditioning systems in London. Both the ABN Amro data centre and Imperial College University E-Science Computer Suite are cooled using CO_2 plants to absorb the intense heat loads produced by the computer blade servers.

In addition, the Office Building of EnergiMidt in Denmark has supplemented the traditional glycol based free cooling system with a pumped CO_2 system for the server cooling. The installation encompasses a cascade CO_2 system with propane compressors. The benefits of phase transition and an increased heat transfer coefficient are utilized and the temperature limit is raised, lowering the annual energy consumption. To further reduce operating costs the heat is recovered from the server room and the canteen refrigeration system by the use of heat pumps. Calculations show a significant reduction in the energy consumption.

PRIVATE RESIDENTIAL HOUSING: REFRIGERATORS, HOT WATER & AIR-CONDITIONING

HC: Across the world there are over 600 million hydrocarbon domestic refrigerators – around 36% of the global market for new domestic refrigerators and freezers today, and estimated to rise to up to 75% by 2020 (TEAP 2010). The refrigerant R600a (isobutane) is widely used in fridges and freezers in Europe, Japan, China, which are also available in South America, Canada and Mexico, and are expected to enter the U.S. now that legislative approval has been granted. Portable air conditioning based on propane has been on the European market since 1985. Australian companies have also been producing a variety of HC-based split-air conditioners for both home and office use. 2011 saw the launch of the first Chinese produced hydrocarbon (R290) room air conditioner mainly for export – an important milestone given that 90% of the world's small air conditioners are manufactured here. All models meet high European safety standards. They conform to the international safety standard IEC 60335-2-40 and are certified by the German Association for Electrical, Electronic & Information Technologies (VDE), one of Europe's largest technical and scientific associations. Moreover, the final product has been certified by global leader in independent testing TÜV. In China 18 of the 32 air conditioning production lines will be converted to R290 as part of the country's HCFC Phase-out Management Plan (HPMP). First projects in India are currently under way to build domestic production lines for HC A/C systems. Overall, HC low charge packaged solutions (less than 1 kg) are expected to see increased use, from a market share of below 1% today.

In light of the Greenfreeze triumph in domestic fridges, the increasing investment in R290 air conditioning systems could pave the way for a similar HC success in small charge applications like room ACs. Other potential applications for HCs include residential heat pump dryers.

CO_2: Carbon dioxide has been extensively used as a refrigerant in domestic hot water heat pumps in Japan, where they were introduced as "Eco Cute" in 2001. The market for CO_2 heat pump water heaters has rapidly expanded with models now available in Europe for space and water heating. Over 2 million residential models can now be found in family homes. Tumble dryers using CO_2 heat pumps are also being researched. Residential air-conditioning using CO_2 is under investigation but still faces energy efficiency challenges.

In addition Norway and Austria have seen 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, under the IEA Heat Pump Programme's collaborative project on "economical heating and cooling systems for low energy houses". Both projects have delivered promising results with high COP values. Prior to this a Norwegian research study also indicated that in low energy and passive houses, where Domestic Hot Water (DHW) heating accounts for 50-85% of the total annual heating demand, an integrated CO_2 heat pump system will outperform the most energy efficient HFC units on the market.

DISTRICT HEATING & COOLING

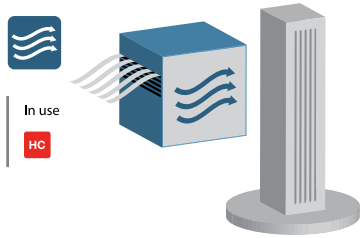
NH_3: Although not yet widely used, ammonia chillers and heat pumps can provide residential and commercial heating and cooling requirements from a central plant via a water piping network. For example, in Drammen in Norway, the background heat from seawater is being harnessed by a single screw ammonia heat pump to provide hot water for the local district heating network. In the US, Montgomery College in Rockville Maryland has used an ammonia district cooling plant since 1994. The Roche Welwyn Garden City, UK site also has a centralised water chilling plant that uses ammonia as the refrigerant.

HC: In Denmark isobutane heat pumps installed in the new central cooling plant of Aarhus University Hospital Skejby supply cooling water to the entire hospital via a new distribution network.

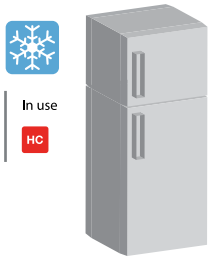
CO_2: A large scale 100% renewable energy project in Denmark incorporates a CO_2 heat pump into a large-scale district heating system. The 1.5 MW (thermal) CO_2 driven heat pump "moves" energy to the energy storage heat pit, providing the whole system with greater flexibility in energy output.

RESIDENTIAL

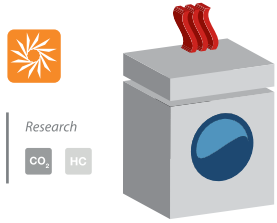
PORTABLE / MOUNTED AIR CONDITIONER



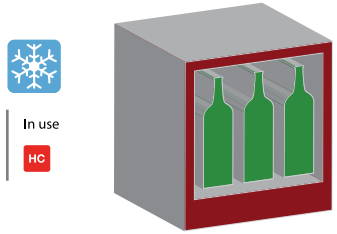
DOMESTIC REFRIGERATOR / FREEZER



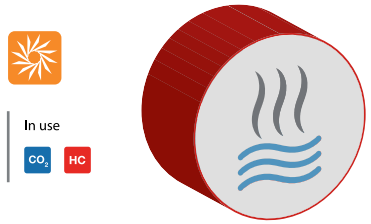
LAUNDRY DRYER



WINE CABINET

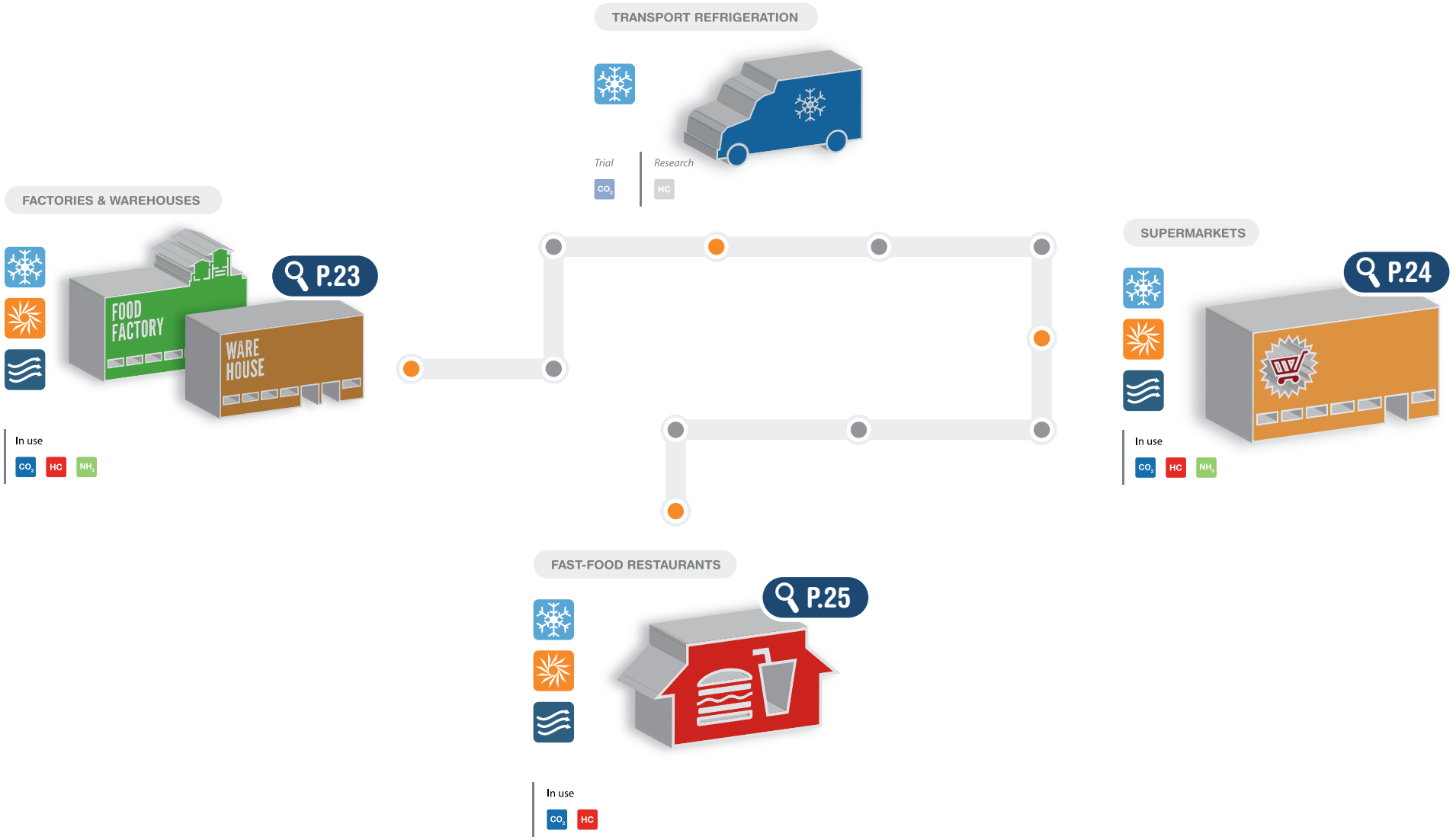


HOT WATER HEATING & SPACE HEATING



NH3 Ammonia | CO2 Carbon Dioxide | HC Hydrocarbons | Refrigeration | Heating | Air Conditioning

THE FOOD CHAIN



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

THE FOOD CHAIN

FOOD PRODUCTION, PROCESSING & COLD STORAGE

NH_3: Traditionally, ammonia-based industrial refrigeration has been the norm in the food processing and preservation industries, given its relatively low capital cost combined with excellent operating performance. Over 80% 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 at 40%. In the food processing industry ammonia can be found in fish, meat and poultry processing plants, confectionary factories, fresh milk and dairy production facilities, wineries and breweries.

Types of installations found in these factories include ammonia blast freezers, spiral freezers, plate freezers, and freezing tunnels. NH_3 is also used in ice flake machines. Many food processing ammonia refrigeration plants now use an integrated heat and refrigeration system. As regards their geographic distribution, NH_3 systems are largely used in the USA, Northern Europe, and Central and Western Europe. In Eastern Europe, including Russia, a traditionally strong ammonia refrigeration engineering base can be found. India uses NH_3 systems to a some extent, with NH_3 used for quick freezing in one of the country's largest food parks. In addition, large NH_3 heat pumps have been used in 5% of industrial air-conditioning systems and in 30% of all applications in developed countries.

CO_2: R744-only refrigeration systems are still used to a lesser extent in the food storage and processing industries and especially in those regions where the use of ammonia is restricted. CO_2 is also used for deep freeze storage and in blast freezers, and in ammonia/CO_2 cascade systems. Market share of CO_2 for industrial refrigeration is at 10% in developed and 0% in developing countries; and for heat pumps 5% and 0%, respectively. Currently the potential of high-capacity carbon dioxide chillers is being investigated, as an alternative to NH_3 chillers. Also within the food industry, 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 can also be used in heating and cooling systems in wine production, such as an integrated CO_2 heat pump, adiabatic fluid cooler and glycol chiller system used in California. Ice flaking machines using carbon dioxide refrigerants have been commercialised and are gaining market share.

NH_3/ CO_2: In Europe several cold storage facilities have been equipped with CO_2/ NH_3 cascade systems, using ammonia at the high stage and carbon dioxide at the low stage. CO_2 is also being used as a secondary refrigerant that is circulated in cold store rooms with the primary refrigerant typically ammonia — confined to the machinary room.

HC: Propane has been used in industrial refrigeration and cooling applications, especially in large chillers where they have been available for over 10 years. As an example from the dairy industry there is a hydrocarbon refrigeration demonstration project for milk coolers in Indonesia. Market share in industrial refrigeration is estimated to be at 0-2% worldwide; for industrial air-conditioning at 10% for developed countries and 5% for developing countries. Again, inadequate technicians' training impede a more wide-spread use of HCs in various countries.

ROAD TRANSPORT REFRIGERATION

CO_2 / HC: Road transport refrigeration is a niche market with special requirements in terms of equipment robustness, weight or corrosion resistance. The market for CO_2

and hydrocarbon refrigerants is still in its infancy with selected food retail chains having equipped first delivery trucks with natural refrigerant systems. Most recently, research has focused on regenerative trailer cooling with natural refrigerants as a means to save up to 20% energy.

SUPERMARKETS: CENTRAL REFRIGERATION

CO_2: Carbon dioxide is used for central refrigeration equipment in supermarkets. 25 Canadian and over 1,300 supermarket stores across Europe have already opted for CO_2 transcritical plants, making it one of the most promising applications for R744. In a recent development, the announcement by a US-American system supplier that it will roll out pilot installations across North America in 2012 has brought additional impetus to the market. Progress in also being made in China where Tesco has opened its first store using CO_2 as the refrigerant. CO_2 is furthermore used in a variety of cascade and secondary system solutions, together with ammonia and hydrocarbons, or synthetic refrigerants. Cascade solutions have become a well-established market especially in Europe. CO_2 flake ice machines for fish filling counters in supermarkets and fishmongers are also commercially available.

HC / NH_3: Unlike many European retailers UK chain Waitrose is investing in propane refrigeration technology, whilst Marks and Spencer has installed several CO_2/propane hybrid systems. At the end of 2011, Tesco opened its first zero carbon store in Thailand, featuring hydrocarbon powered fridges. For condensing units in medium-sized convenience stores, both CO_2 and HCs can be a preferred option also for developing countries.

CO_2 / NH_3: Ammonia is mostly used in NH_3/CO_2 cascade solutions, which are estimated to have an up to 5% market share in developed countries. In South Africa a Pick and Pay supermarket has replaced the conventional centralised refrigeration system with a 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 SYSTEMS: DISPLAY CABINETS, ICE CREAM FREEZERS AND VENDING MACHINES

HC / CO_2: In a supermarket environment, a variety of hydrocarbon cabinets, including island and multideck displays, chest and upright freezers, ice cream freezers and bottle coolers are commercially available. For example, Danone and Nestlé have several thousand coolers using hydrocarbon technology across a number of countries including Denmark, Mexico and Germany, whilst by 2010 PepsiCo had deployed 61,419 hydrocarbon and 277 CO_2 units globally. As other examples of industry commitment driving the market, by the end of 2011, the Coca-Cola Company had exceeded 420,000 HFC-free vending machines, coolers and drinks dispensers using both CO_2 and hydrocarbons, whilst Unilever had rolled-out 800,000 hydrocarbon ice cream freezer cabinets. Beer manufacturer Carlsberg has over 3,500 hydrocarbon coolers. In addition, an Italian frozen desert equipment manufacturer has produced a prototype ice cream machine using CO_2 technology, whilst an Italian and British display cabinet manufacturer have developed CO_2 cabinets and wine walls.

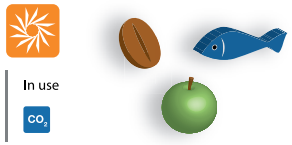
FAST FOOD RESTAURANT: DRINKS DISPENSER, ICE CUBE MACHINES AND MEAT FREEZERS

HC / CO_2: The use of natural refrigerants in point-of-sale appliances has also been driven by McDonald's, which opened three HFC-free restaurants using hydrocarbons and CO_2 technology, in addition to a Japanese and French restaurant which have each installed a CO_2 heat pump. The franchising group has developed natural refrigerant alternatives for eight pieces of refrigeration equipment, including: juice dispenser, ice cube machine, salad cooler, and the meat/wall freezer. While the smaller refrigeration applications have been covered by hydrocarbon refrigerants, CO_2 was used in space heating and cooling, as well as in the refrigeration rooms.

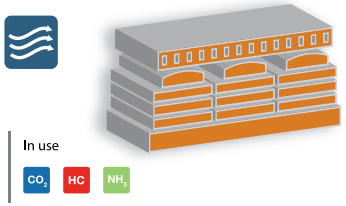
FOOD FACTORIES & WAREHOUSES

FOOD & DRINKS PRODUCTION I FREEZING
(frozen food production, meats, fish, etc...)

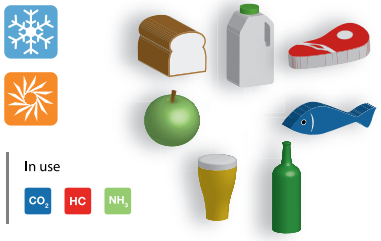
FOOD & DRINKS PRODUCTION I DRYING
(fruits, coffee, fish, etc...)



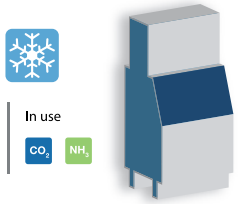
INDUSTRIAL PLANTS I CHILLERS



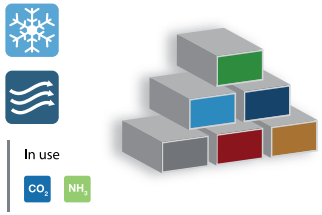
FOOD & DRINKS PRODUCTION I REFRIGERATION & HEATING
(bakery products, dairies, meats, fruits, fish, breweries, wineries etc...)



ICE FLAKE MACHINES

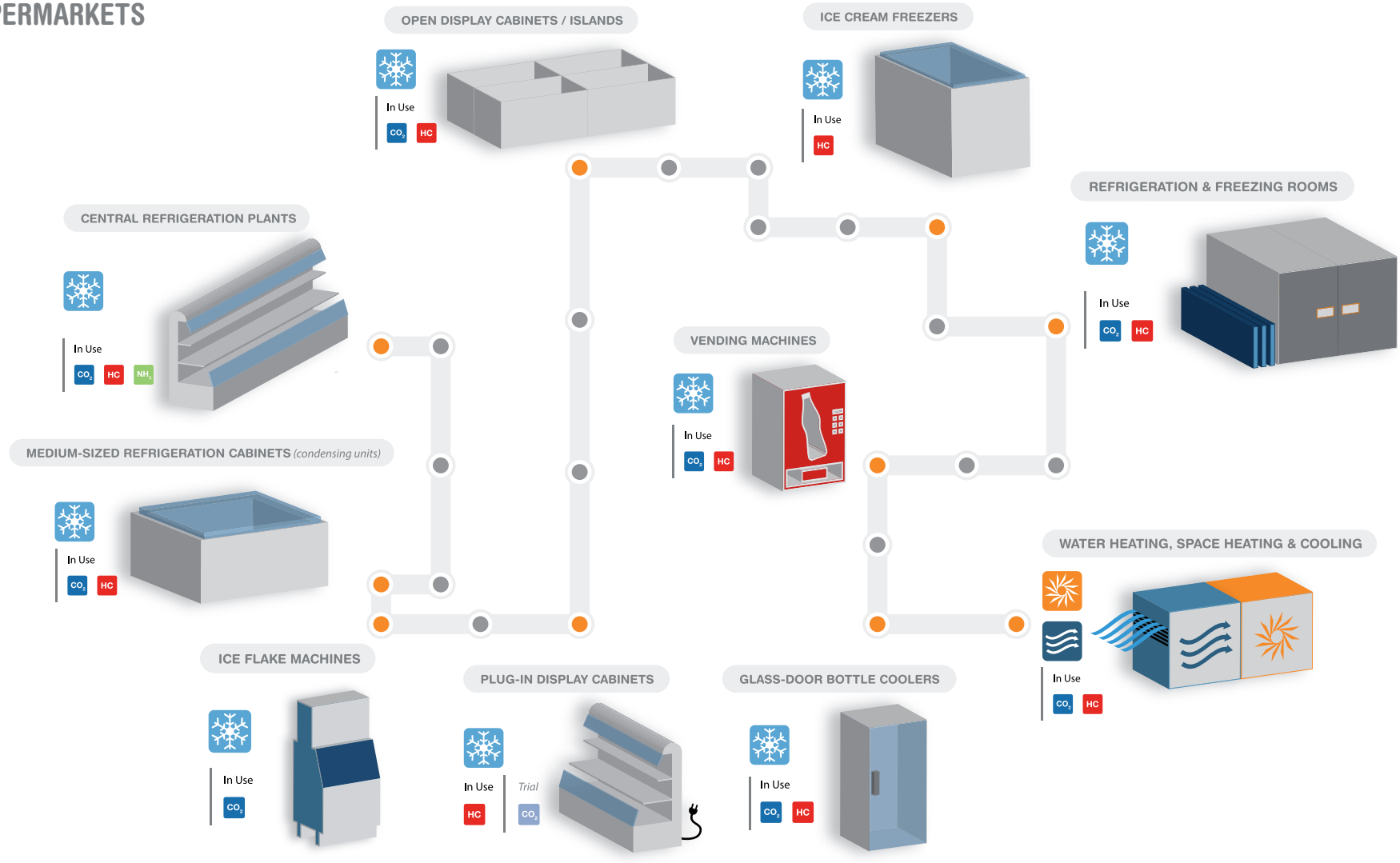


COLD STORAGE



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

SUPERMARKETS

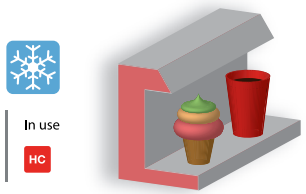


NH3 Ammonia | CO2 Carbon Dioxide | HC Hydrocarbons | Refrigeration | Heating | Air Conditioning

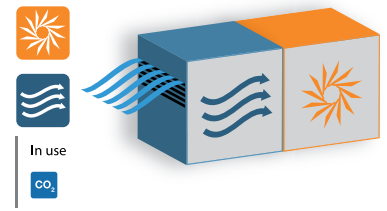
FAST FOOD RESTAURANTS

COLD DRINK DISPENSERS & ICE CUBE MACHINES

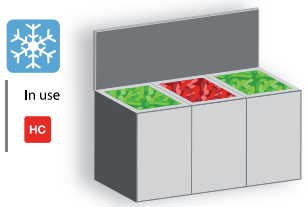
SODA MACHINES, MILKSHAKE & ICE-CREAM MACHINES



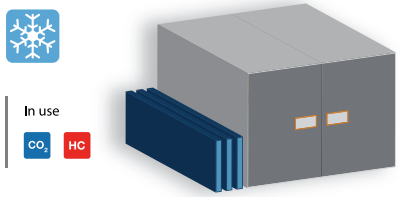
WATER HEATING, SPACE HEATING & COOLING



SALAD REFRIGERATORS



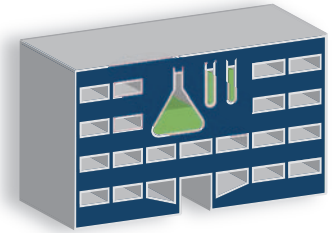
REFRIGERATION & FREEZING ROOMS



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

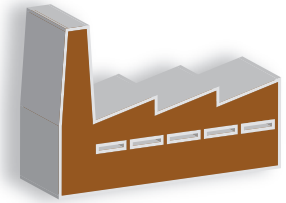
INDUSTRY AND SPECIAL APPLICATIONS

INDUSTRIAL PROCESSES & LABORATORIES



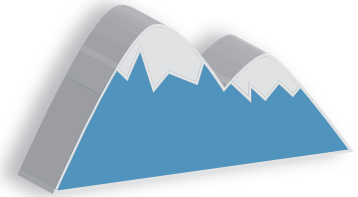
In use HC NH_3 | *Trial* CO_2

PETROCHEMICAL PLANTS



In use HC

SKI SLOPES / BOBSLEIGH

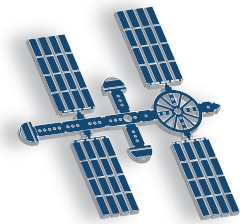


In use NH_3

VACCINE COOLERS

In use HC

INTERNATIONAL SPACE STATION / BIOSPHERE



In use NH_3

DEEP MINING

In use NH_3

ICE RINKS

In use CO_2 NH_3

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

INDUSTRY AND SPECIAL APPLICATIONS

INDUSTRIAL PROCESSES & LABORATORIES

NH_3 / HC / CO_2: For many years ammonia has been the refrigerant of choice for manufacturing sites, for example, Xerox and Fujifilm plants both use ammonia refrigeration, and as a secondary refrigerant for mine air conditioning. Hydrocarbon refrigeration has been used to a certain extent in the chemical industries for the liquefaction of CO_2 and other gases. In oil refineries, and petrochemical plants, hydrocarbon refrigeration is used to maintain certain processes at their needed low temperatures (for example, in alkylation of butenes and butane to produce a high octane gasoline component). There are also examples of hydrocarbon and ammonia chillers in the pharmaceutical industry. Both the Roche Indianapolis campus and Roche Ireland Ltd, which produces active pharmaceutical ingredients, have invested in centralised ammonia chiller plants, whilst at its German logistics centre Roche is using a mixture of ammonia, propane and CO_2. Moreover, the Roche UK headquarters two ammonia chillers and three hydrocarbon chillers provide the office air conditioning and computer server room cooling. CO_2 has become an interesting option for laboratory coolers and freezers in North America and Europe, including in a laboratory refrigeration plant in Québec used for testing natural refrigerants, whilst a laboratory freezer has been converted to hydrocarbons.

SOLAR REFRIGERATION: VACCINE COOLERS & FOOD REFRIGERATORS

HC: In the last decade several companies have developed hydrocarbon (R600a) solar powered vaccine coolers, including Danish, British, as well as a refrigiration manufacturer from Swaziland, which presented its first prototype vaccine coolers in 2010. These unique coolers can operate on intermittent or poor mains supply, battery-free solar power or a combination of the two. The "SolarChill" cooler using only HCs for refrigeration and foams was developed and supported by various manufacturers, UNEP, UNICEF and GIZ.

A $2.7 US million (€2 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

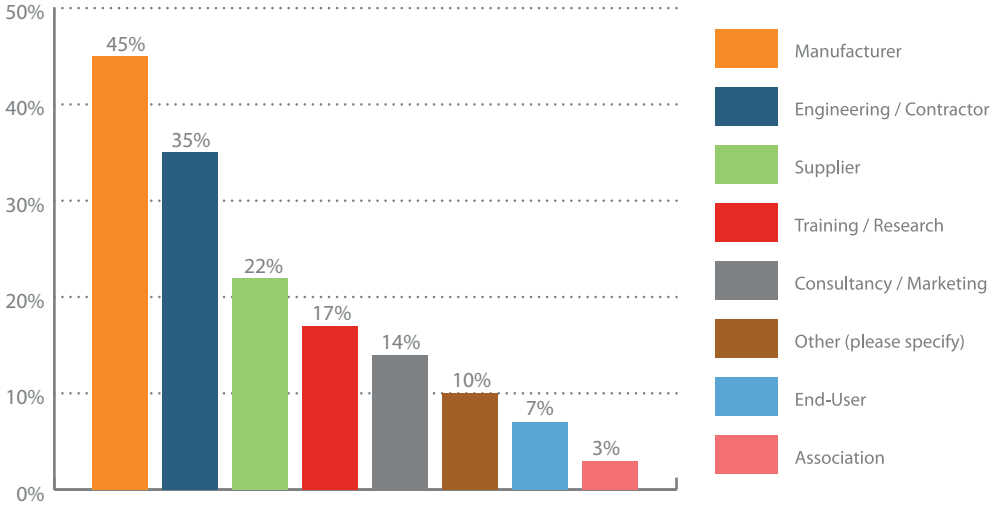
NH_3: Ammonia has become increasingly popular in recent years for cooling ice rinks due to the HCFC phase-out. Several European ice rinks use ammonia refrigeration systems, including "Curl Aberdeen" ice rink in Scotland, Europe's largest open-air stadium with an ice rink (Karlstad, Sweden), and the iconic Alexandra Palace in London, UK. Ammonia refrigeration has also been used to refrigerate temporary ice rinks, such as for example the outdoor rink used for the US ice hockey league in Chicago in 2009. Other winter sport applications using ammonia refrigeration include the SNORAS indoor skiing Snow Arena in Lithuania and the world's third largest indoor snow park in Dubai, the main attraction at the Mall of the Emirates shopping centre in Dubai, which offers 5 ski slopes and is covered with 6000t of snow. The bobsleigh, luge and skeleton refrigerated tracks in Vancouver, Canada, used for the Winter Olympics and in Königssee, Germany, used for the 2011 World Cup, also use ammonia.

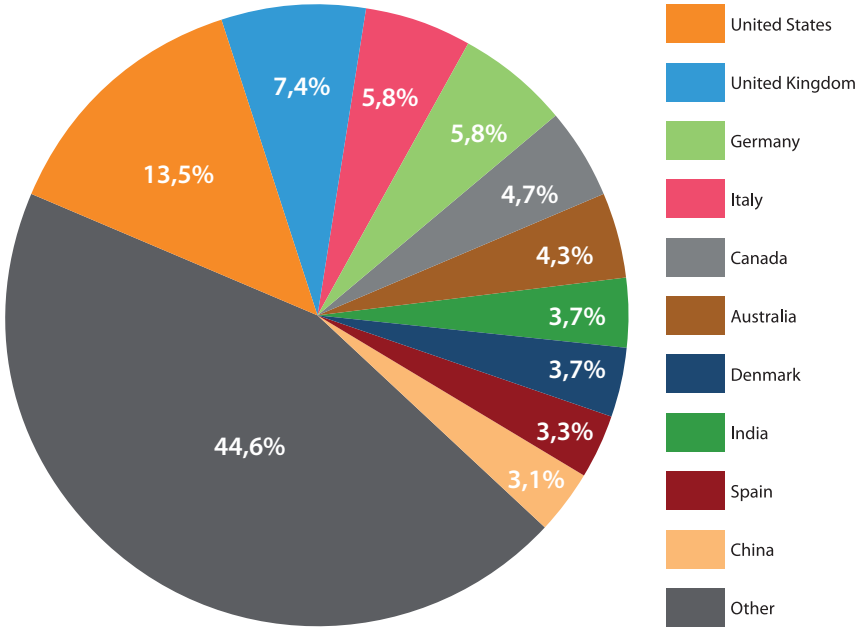
CO_2: The world's first ice ink using 100% CO_2 refrigeration was installed in 2010 in Arena Marcel Dutil in Quebec, Canada. It received ASHRAE's Technology Award for Industrial Facilities in 2011.

SPECIAL APPLICATIONS: SPACE STATION & BIOSPHERE

NH_3: The most prominent examples of the use of ammonia in special applications are for air-conditioning in the international space shuttle and the ecosystems of the Biosphere II research project in Arizona, which will be used in the future for climate change research.

GLOBAL INDUSTRY SURVEY – RESPONDENTS PROFILES





ORGANISATION TYPES & MAIN ACTIVITIES

The 1,254 HVAC&R professionals and end-users surveyed from March to September 2011 mainly represented manufacturers (45%) and engineering & contracting firms (35%). As multiple choices were possible, representatives of corporations offering solutions for various phases in the value chain of system development, supply and maintenance, indicated more than one activity. The two main industry sectors represented were commercial refrigeration (65%) and industrial refrigeration (62%), followed by stationary air-conditioning (48%).

COUNTRIES REPRESENTED

The highest share of respondents were located in the USA, traditionally a strong user of ammonia systems but the world's last major market to receive government approval to use hydrocarbons as a refrigerant. It is followed by the UK, Italy and Germany. Australia, Canada and India were represented with around 4-5% each, whereas Denmark – despite being the smallest country in this top group by far – showed its natural refrigerant leadership role also in a high response rate.

GLOBAL INDUSTRY SURVEY ON NATURAL REFRIGERANTS

To quantify the global market for natural refrigerants carbon dioxide (CO_2), ammonia (NH_3), and hydrocarbons (HCs), an online survey was sent to more than 6,000 HVAC&R professionals, and relevant industry associations. The total universal response set used in the following was 1,254 individuals.

Specific objectives of the survey were to identify expectations and priorities of the HVAC&R sector; discover the perceived drivers and barriers affecting the uptake of natural refrigerants; and determine the level of awareness and support for natural refrigerants. This was the first time that an industry-specific survey was conducted focusing exclusively on the market potential of natural working fluids in different applications, sub-sectors and geographic regions. The comparatively high response rate showed that interest in more reliable data on the economic prospects and drivers are sought by the industry which is (still) highly heterogeneous, depending on natural refrigerant selected and end-use application.

METHODOLOGY

The online survey has been active since 1 February 2011 and consists of a mixture of 28 structured (closed-ended) and unstructured (open-ended) questions. The question set was fielded online to targeted representatives of key HVAC&R organisations and companies around the world, including system manufacturers, component suppliers and end-users. Over 6,000 invitations to participate were sent by email. Selected industry associations, including AIRAH[1], AREA[2], BRA[3], EHPA[4], Green Cooling Association, GreenChill program, and REHVA[5] supported the distribution of the survey among the associations' members.

By 15 November 2011, the survey had received a total of 1,338 responses. To avoid overrepresentation of individuals in the form of double responses, access is automatically restricted to a one time data entry per IP address. To enable a reliable analysis, data received up to 31 September was taken into account in the drafting of this guide – in total 1,254 individual responses.

The survey was of a voluntary nature. A balanced representation of HVAC&R professionals in terms of geographic distribution, main types of activities and prior experience with natural refrigerants was aimed for by involving neutral industry associations. To increase the response rate participants were informed that by participating they could get access to preliminary data and choose for their organisation to be included in a directory in the forthcoming *Guide: Natural Refrigerants Market growth for Europe*. This, and the fact that the initial database contained a high sample of individuals familiar with and/or involved in offering natural refrigerant technologies and services, led to a relative overrepresentation of the "pro-Natural Refrigerant" industry; those that already offer and/or are willing to offer in the future solutions based on CO_2, NH_3 and HCs. Overall and not surprisingly, it can be concluded that, due to the survey's voluntary nature, the question set attracted a higher-than-average number of respondents already interested in the future of natural working fluids.

To avoid bias as far as possible however, wherever there were marked differences in response patterns from the total data set, a separate sub-set containing only individuals with no current or future natural refrigerant products was formed and contrasted with the parent population. This allows for a clear distinction between "pro-Natural Refrigerant" respondents and those not planning on marketing solutions based on natural working fluids anytime soon.

1 Australian Institute of Refrigeration, Air-conditioning & Heating

2 Air-conditioning & Refrigeration European Association

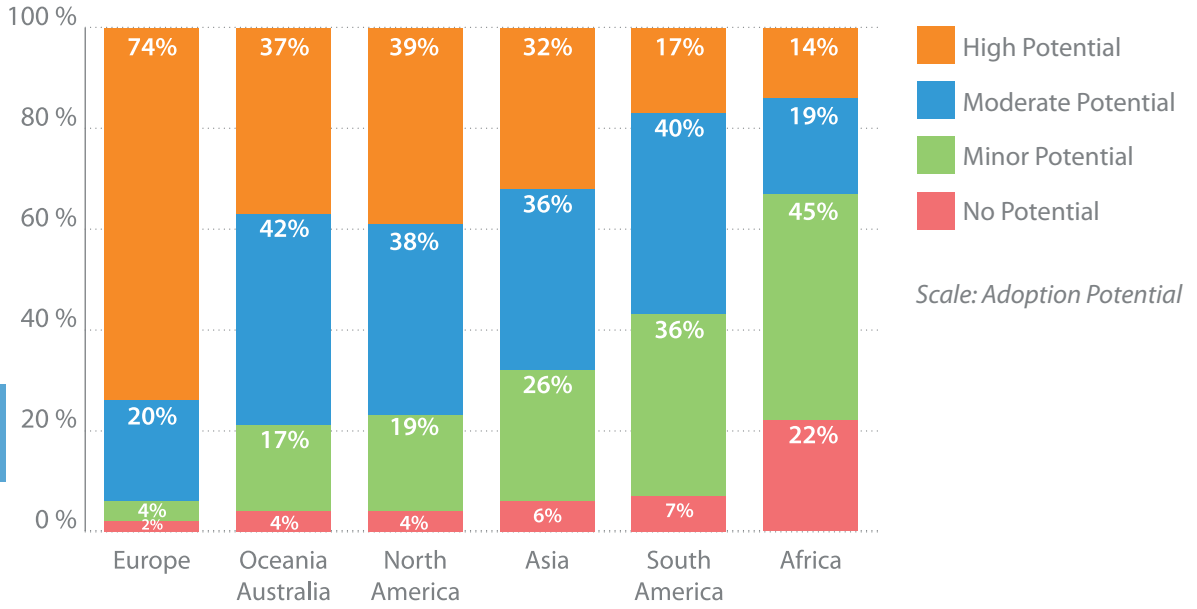
3 British Refrigeration Association

4 European Heat Pump Association

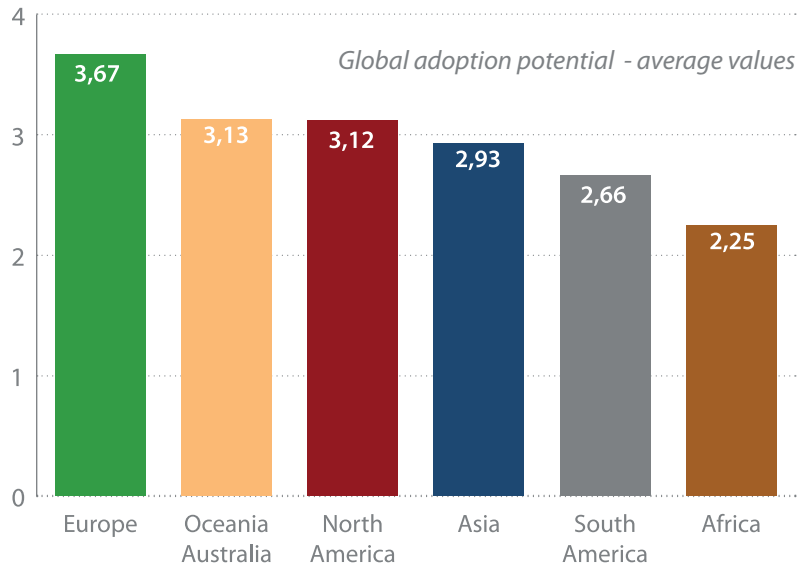
5 Federation of European Heating, Ventilation & Air -conditioning Associations

GLOBAL ADOPTION POTENTIAL

QUESTION: "Rank the following world regions by overall Natural Refrigerants Market Adoption Potential".



Scale: Adoption Potential



Total responses: 975

EUROPE SETS THE TONE FOR THE ADOPTION OF NATURAL REFRIGERANTS

An overwhelming majority - around 74% of the 1,000 industry expert respondents to the global HVAC&R survey believe that Europe shows "high" potential for the market uptake of CO_2, NH_3 and the group of hydrocarbons used as refrigerants. This also confirms that acquired competences of European-based corporations in natural refrigerant technology will remain a solid basis for supplying domestic and overseas markets with HFC-free solutions for the foreseeable future.

Europe is followed by Oceania/Australia, North America and Asia where an overall "moderate" market potential for natural working fluids exists, but where on average a third of all respondents still see a "high" adoption rate. Minor leadership potential, on the contrary, is recorded for South America and especially Africa, with only 17% and 14% of respondents believing that non-fluorinated gases will have a "high" potential to be adopted in the near future.

DORIN innovation

Environment First !

HYDROCARBONS COMPRESSORS: "HEX" RANGE

Compressors belonging to HEX range are designed according to the safety requirements imposed for the use in flammable risky areas (zone 2, gas group IIB), as defined in ATEX 94/9/CE, featuring electric component conforming to such directive (exception made for INT69).

The range covers displacements from 2.89 to 221.75 m^3/h and nominal capacities from 0.5 to 80 hp.

The main characteristics of our compressors are:

- high C.O.P. values, thanks to fluid dynamic optimization of the internal vanes shape, to high efficiency motors and high tech components
- suitable for all the main refrigerants available: HC (R290 and R1270) and HFC (R404A, R134a, R407C, R507)
- very low noise level
- available on request for frequency variations
- standard electrical box IP65
- PTC sensor for discharge temperature control standard for the entire range
- special oil sight glass (exception made for HEX1)
- mineral oil with high viscosity (68) for HC (R290 and R1270) and POE for HFC (R404A, R134a, R407C, R507)
- special heads for ranges HEX1, HEX2, HEX32 and HEX34
- special oil differential pressure sensor, category 3G, protection rating Ex nA (standard for HEX5, HEX6 and HEX7)
- special accessories, category 3G, protection rating Ex nA applying to crankcase heater, coils for capacity regulation and unloaded start

CARBON DIOXIDE COMPRESSORS: "CD" RANGE

DORIN broadens CO_2 compressors availability with its CD range, consisting of following models

CD-H: Single stage compressor able to operate in trans-critical conditions. Perfectly suitable for

- heat pumps application
- Commercial refrigeration (MT)
- refrigerated transport
- HVAC systems (reversible and not)

CD-M: Single stage compressor able to operate in trans-critical conditions. Perfectly suitable for

- Commercial refrigeration (MT)
- refrigerated transport

CD-B: Single stage compressors for booster and/or cascade applications, featuring:

- high Pss value, thus improving LT system safety margins during prolonged standstill
- specifically designed electric motors to cope with typical LT loads

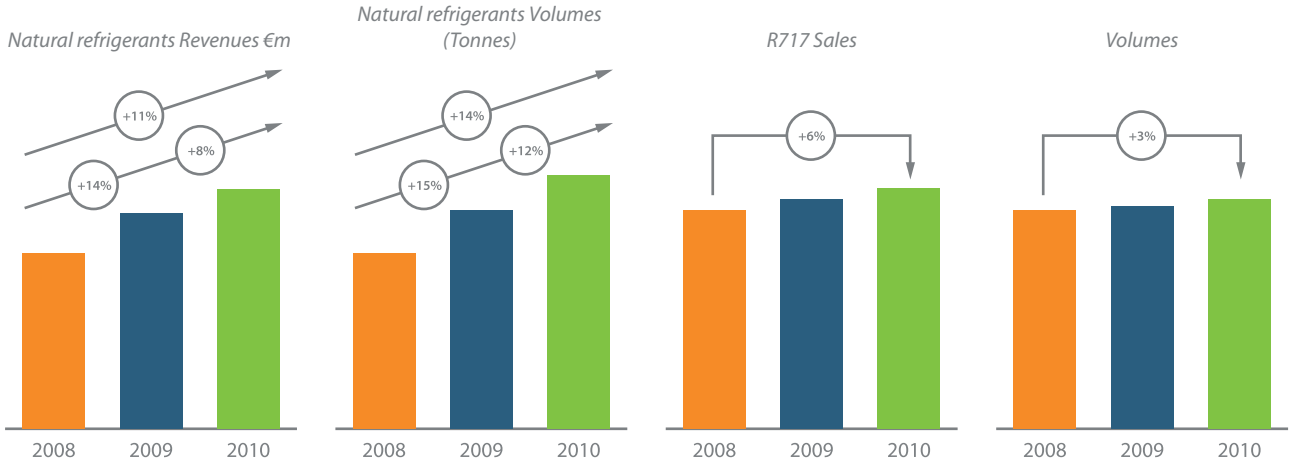
CD-2S: Double stage compressors able to operate in trans-critical conditions. Perfectly suitable for:

- commercial refrigeration (BT)
- refrigerated transport

Considering the operating conditions of a trans-critical CO_2 compressor, it has been decided to develop a completely new compressor platform, without trying to modify a standard HFCs compressor. The design has been developed using the most modern solid modelling codes, like, for instance, FEM analysis.

Particular attention has been given to heat transfer phenomena between compressor HP and LP side. This led to the introduction of an innovative compressor design which permits extremely high COP values.

NATURAL REFRIGERANT SALES TRENDS



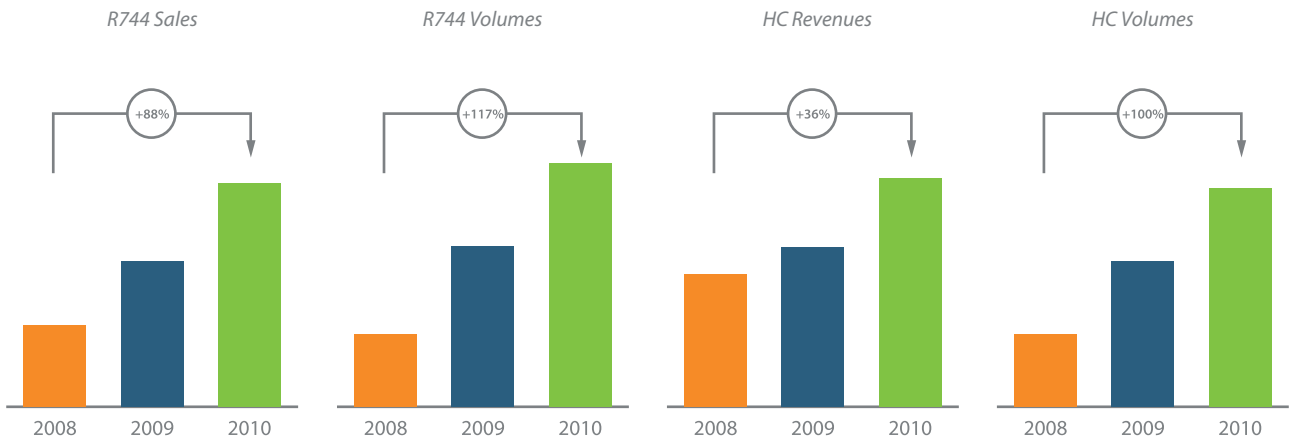
A GROWING MARKET FOR CO_2, NH_3, HCs

Overall, the market for the three natural refrigerants ammonia (R717), carbon dioxide (R744) and the group of hydrocarbons - mostly propane R290, isobutane R600a, propylene R1270, and ethylene R1150 - is experiencing significant growth.

Based on data of a leading refrigerant supplier with a global presence, the total market for natural refrigerants is growing, with a 11% reported increase in revenues, and a 14% increase in volumes per annum from 2008 to 2010. However, growth within the total natural refrigerants market differs significantly for CO_2, hydrocarbons and ammonia. While ammonia is the most-established market, by far, CO_2 and hydrocarbons have shown strong double-digit revenue & volume growth. The relative increase of sales and volumes indicated by the supplier is a good indicator for global trends, given that the supplier's market share within the natural refrigerant supply remained relatively constant over the reported period.

AMMONIA: MATURE AND STABLE MARKETS

Ammonia today is the most-established refrigerant market with large sales in terms of volumes and revenues. As a result, it has shown only modest growth over the last few years, with a reported increase of 6% in sales, and 3% in volumes, respectively. Regarding its geographic distribution, all world regions use ammonia, with the cold chain and food-processing industries particularly reliant on the natural refrigerant.

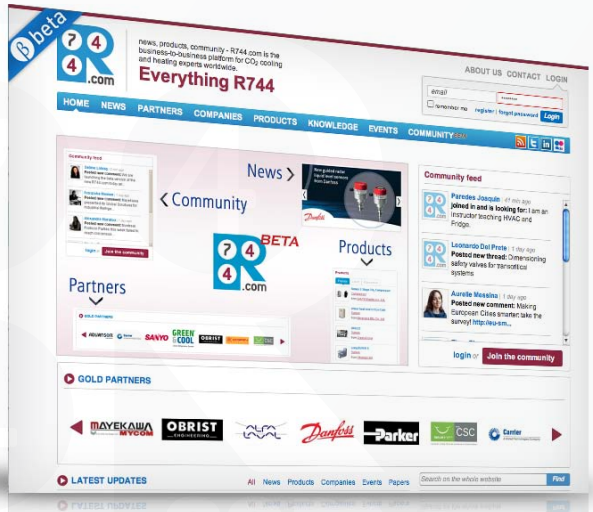


CARBON DIOXIDE: A RISING STAR

For the selected refrigerant supplier, R744 sales have increased by 88% from 2008 to 2010, and volumes by 117% over the same period. This growth is mainly driven by Western Europe that is demanding CO_2 for commercial refrigeration. Americas, Asia-Pacific, the Middle East and Eastern Europe still show a very small market, which is unsurprising given the limited use of CO_2 in supermarket refrigeration, and its still lower thermal efficiency at high ambient temperatures.

HYDROCARBONS: ASIA-PACIFIC LEADING THE WAY

Over the last 3 years, the Asia-Pacific region has driven growth in sales of hydrocarbon (HC) refrigerants. In the Americas, HC sales are dominated by domestic appliances in South America but are expected to pick up also in North America now that the US EPA has approved their use. Global revenues increased by 36% and volumes by 100% in the period 2008-2010, with the difference between volume and revenue due to higher volume demand of lower cost/kg products.



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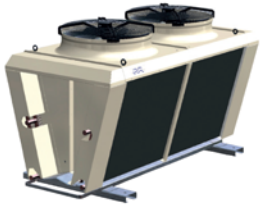

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END USER VIEWS ON NATURAL REFRIGERANTS

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

" In terms of rollout in developing and emerging economies we need to see investment in training to support the units once they are in service. We know that when you are going into a new market with a new technology that has to go lock-step with the investment in training, and people running training companies need to think about whether they are geared up to service these units. On the policy side, it would be whether there is any scope for the things like the Montreal Protocol to be extended to include natural refrigerants so that we can use the funding that is available through those channels to support the transition, not just from HCFC to HFC but from HCFC to leapfrog into natural refrigerants. It's a big ask, it involves an international multilateral process, but we could see a real step change if we could get some kind of agreement like that."

Thomas Lingard, Unilever

"In addressing cooling technologies, governments must initiate a strong first step of setting a phase-out date for HFCs and mandate natural refrigerants as the only acceptable form of cooling gases. Simultaneously, they must tax the use of HFCs as an incentive for the development and commercialization of HFC-free technologies. Finally, to ensure success, the industry needs an accompanying knowledge and training network to address operational concerns."

Antoine Azar, The Coca-Cola Company

"McDonald's Germany opened the first HFC-free restaurant in Heidelberg in October 2011. Resulting from our experience with the HFC-free restaurant, availability is amongst our top priorities when it comes to making natural refrigerants widely accessible to the market. Suitable equipment that is ready and available is indispensable. A second priority is cost-effectiveness. The equipment operating on natural refrigerants needs to be profitable in operation. Otherwise, companies will not invest in it. Moreover, solutions for cooling and air conditioning have to be operable in order to set valuable incentives for changing to natural refrigerants. Thus, operability is a third priority for bringing natural refrigerants to the market.

Achieving these three priorities requires more commitment from companies and politicians alike. Our suppliers have already recognized these requirements. After the testing phase, they will continue to develop the instrumentation to make it marketable. However, in order to produce HFC-free equipment that is readily available, cost-effective as well as operationable, more stakeholder engagement is necessary."

McDonald's

"1. HEINEKEN would focus on stimulating EcoDesign for further reductions in energy consumption and improvement of natural refrigerant applications

2. HEINEKEN would focus on ensuring that appliances comply with applicable legislation and the development of industry standards for cooling and refrigeration

3. HEINEKEN would focus on increasing availability of natural refrigerants and thereby achieving economies of scale

HEINEKEN has chosen to invest in natural refrigerants because of the better environmental performance, in terms of energy use and carbon footprint impact, and because of the value it offers to our customers. "

HEINEKEN

"You have to look first at labelling and certification in a refrigeration training program. Technical issues can be discussed forever, but they can be resolved. I would imbed certification for refrigerant training and labelling in a comprehensive system and have this certification system not only cover natural refrigerants but all refrigerants. This will also create confidence at the customer or end-user level. Regarding equipment costs one could steer the selection of natural refrigerants in a first instance through the lowering of taxes, while also introducing higher taxes on high GWP refrigerants."

Dr. Lambert Kuijpers, University Eindhoven

"My top 3 priorities to bring natural refrigerants faster to market would be:

1. Implement hybrid refrigeration systems (i.e. CO_2/R134a) before setting up 100% natural refrigeration, especially in countries where ammonia and/or CO_2 transcritical design is not yet mature.

2. Convince refrigeration manufacturers/installers that standardization and built-in rack compressors must help to reduce the price difference between conventional and natural refrigeration systems.

3. Promote to installers that the future of refrigeration is to switch their activity to natural refrigeration through training, certification, etc."

Jean-Michel Fleury, Carrefour

"1. Encourage end users to "Go for it"! The technology is here – and it works! To us (Coop Norway), it seems there is enough experience and studies that prove natural refrigerants' success, environmentally and economically.

2. Although hardly the fastest approach; political action in order to increase (and harmonise) taxes on synthetic refrigerants.

3. "Ally" with producers, in order to continue developing the technology."

Knut Lutnæs, Coop Norway

"1. There is one main reason which speaks against CO_2 systems and this must be fixed: Price reduction of CO_2 systems to the level of conventional cooling systems;

2. Development of low-cost compact systems for small convenience stores"

Elias Steiner, SPAR Switzerland

"To incentivise investment in natural refrigerants we need:

1. Education for designers

2. Test natural refrigerant installations in all countries and educate maintenance technicians about the technology.

3. Further educate end-users and contractors about the natural refrigerant installation options."

Ilpo Hakkarainen, Kesko Finland

"To begin with we need to address education of the professionals in the refrigeration industry, which means the planners, the installers and also the technicians operating and maintaining the systems. Secondly, the manufacturers need to undertake more R&D on components such as compressors and regulation valves. Thirdly I think we need certain guidelines from the legislative point of view, such as a tax on HFCs or guidelines recommending the use of CO_2 in certain applications."

Urs Berger, Migros

"Delhaize Belgium is one of the frontrunners bringing natural refrigerants to its supermarkets by using CO_2 exclusively for negative installations. Its top 3 priorities to bring natural refrigerants faster to market would be:

1. To have encouraging incentives from authorities promoting faster retrofit/renewal of existing installations

2. Transform old installations R22 (two stage compressors) directly to CO_2

3. Bring together constructors/producers/users to find new uses with natural refrigerants like propane,…

Delhaize has chosen to invest in natural refrigerants because...

1. It is more environmental friendly

2. It is more efficient on the energy side

3. In case of leaks, there is no impact on greenhouse gas (GHG) emissions

4. Technology, like sub-critical installation, is reliable

5. Prices of installation are becoming more and more competitive"

Delhaize Belgium

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EUROPE TODAY

TECHNOLOGY & MARKETS

TECHNOLOGY: USE POTENTIAL FOR NATURAL REFRIGERANTS

As the world market with the highest present potential for natural working fluids, Europe's markets for heating, refrigeration and air-conditioning show different capacities to revert to or remain "natural". See a simple table rating the stage of technology development for ammonia, carbon dioxide and hydrocarbons systems in selected end-use applications which serves as a starting point for keeping track of future technology advances, on…

PAGE 40

POLICY: AN EVALUATION GRID FOR EU LEGISLATION

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 European Union legislation and initiatives as regards their impact on adopting HFC-free solutions, their overall enforcement potential, and their vision & sustainability, as well as outstanding national strategies serving as a role model, on…

PAGE 44

A SUCCESS STORY: CO_2 TRANSCRITICAL SUPERMARKETS

With an estimated 1,300+ European food retail stores using CO_2 transcritical refrigeration systems, their use is constantly spreading from a few leadership markets to other countries, pushing the "temperature equator" for an energy-efficient use of R744 further south. See a map showing the CO_2-only supermarkets per European country, and the reasons why different national strategies can lead to the same favourable result for HFC-free solutions, on…

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TECHNOLOGY: USE POTENTIAL FOR NATURAL REFRIGERANTS

STATE OF TECHNOLOGY: NATURAL REFRIGERANTS IN EUROPE

● ● ● | COMMERCIALLY AVAILABLE

● ● | PROTOTYPE/TESTING/ DEMONSTRATION PROJECT

● | EARLY STAGE DEVELOPMENT

Application	Sub-Application	CO_2	NH_3	HC
INDUSTRIAL REFRIGERATION	Cold Storage (eg raw fruits and vegetables)	● ● ●	● ● ●	
	Distribution Centre	● ● ●	● ● ●	
	Frozen Food, Meat, Poulty and Fish, Diary and Ice Cream, and Confectionery Processing Refrigeration Plants	● ● ●	● ● ●	● ● ●
	Beverage Production, Brewery, and Wine Refrigeration Plants	● ●	● ● ●	
	Ice Making Plant & Ice Flake Machines	● ● ●	● ● ●	
	Ice Rinks	● ● ●	● ● ●	
	Bobsleigh, Skeleton, Luge Track, and Indoor Ski Centre		● ● ●	
	Pharmaceutical, Chemical, Petrochemical and Process Industries (blood and antibiotic storage, separation and condensations of gases)		● ● ●	● ● ●
	Construction (Setting of concrete, eg Hoover Dam construction)		● ● ●	
COMMERCIAL REFRIGERATION	Supermarket centralised refrigeration plants for cooling large and medium-sized cabinets	● ● ●	● ● ●	● ● ●
	Ice Flake Machines	● ● ●		

STATE OF TECHNOLOGY: NATURAL REFRIGERANTS IN EUROPE

● ● ● | COMMERCIALLY AVAILABLE

● ● | PROTOTYPE/TESTING/ DEMONSTRATION PROJECT

● | EARLY STAGE DEVELOPMENT

Application	Sub-Application	CO_2	NH_3	HC
INDUSTRIAL AND COMMERCIAL AIR CONDITIONING	Mining (Surface chillers)		● ● ●	
	Data Centre Server Cooling	● ● ●		● ●
	District Cooling		●	
	Factory Production Lines		● ● ●	
	Laboratory AC		● ● ●	
	Large Commercial & Public Buildings	● ●	● ● ●	● ● ●
LIGHT COMMERCIAL REFRIGERATION	Plug-in Display Cabinets	● ●		● ● ●
	Ice Cream Freezers			● ● ●
	Ice Cream and Milkshake Machines	●		● ● ●
	Glass Door Bottle Coolers	● ● ●		● ● ●
	Vending Machines	● ● ●		● ● ●
	Water Fountains			● ● ●
	Drink Dispensers			● ●
	Salad Refrigerators			● ●
	Ice Cube Machines			● ●
	Vaccine Coolers			● ● ●

STATE OF TECHNOLOGY: NATURAL REFRIGERANTS IN EUROPE

● ● ● | COMMERCIALLY AVAILABLE

● ● | PROTOTYPE/TESTING/ DEMONSTRATION PROJECT

● | EARLY STAGE DEVELOPMENT

Application	Sub-Application	CO_2	NH_3	HC
INDUSTRIAL AND COMMERCIAL HEATING	Heat Pump Dryer Food processing	● ● ●		
	District Heating	● ●	● ●	● ●
	Large Commercial & Public Buildings (eg hotel hot water heating, fast food restaurant space heating, hospital and nursing home hot water heating)	● ● ●	● ● ●	
	Dairy and brewery heat pump for heat recovery	● ● ●	● ● ●	
RESIDENTIAL AIR CONDITIONING, REFRIGERATION AND HEATING	Portable AC			● ● ●
	Window or Split Type AC			● ● ●
	Domestic Hot Water Heat Pumps for space heating and hot water	● ● ●		● ●
	Domestic Refrigerators and Freezers			● ● ●
	Laundry Dryers	●		●
TRANSPORT AIR CONDITIONING, HEATING AND REFRIGERATION	Passenger Cars AC	● ●		● ● ●
	Electric Cars AC	● ●		
	Buses/ Trucks AC	● ●		● ●
	Truck Refrigeration	●		●
	Trains AC/ Heating	●		
	Cargo Reefer Ship Refrigeration	● ●		
	Fishing Vessels/ Trawler Refrigeration	● ● ●	● ● ●	

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EU POLICIES: NATURAL REFRIGERANTS, VISION & ENFORCEABILITY

INTRODUCTION & METHODOLOGY

This section provides an overview of selected policy initiatives in the European Union (EU) that have an impact on the HVAC&R industry in general and the uptake of natural refrigerants in particular. Best practice policy initiatives at the national level in two European countries are also discussed, as well as an example of one national regulation that restricts the use of natural refrigerants.

THE IMPACT OF EU INITIATIVES IS ASSESSED FOR THREE MAIN CRITERIA, NAMELY:

NR - Natural Refrigerants: This analysis rates the individual legislation regarding its impact on the uptake of Natural Refrigerants. The indicators selected are training & know-how, technology & safety, awareness & psychology, and economy & costs – representing four of the most challenging areas with influence on a wide-spread use of CO_2, NH_3 and HCs.

VS - Vision & Sustainability: This criteria has been selected to portray the overall ambition of the legislation to be in line with the EU's medium to long term strategy in the areas of sustainable consumption & production, and environmental leadership. Besides overall vision, specific criteria for economy (dynamic efficiency), environment (ecological safety), and social aspects (fairness) have been selected as indicators.

EE - Effectiveness & Enforceability: Even with potentially positive effects on environmental leadership in general and/or the support for HFC-free solutions in particular, a piece of legislation not accessible for the intended stakeholder group and with limited enforceability will not lead to strong results in the marketplace. This criteria hence looks at the "practical" process of adoption, implementation and compliance, as well as the policy's flexibility to adapt to changing industry/policy frameworks. For each criterion, the policy initiative uses 4 indicators. The rating for each indicator ranges from 0 (no impact) to 4 (high impact), giving an assessment of the magnitude of the impact.

AN OVERVIEW OF THE 12 INDICATORS:

NR - Training & Know-How: This analyses how the legislation affects the creation of necessary skills to handle natural refrigerants, including certification for the manufacture, supply, commissioning, installation, maintenance / monitoring and decomissioning of HFC-free systems.

NR - Technology & Safety: How the policy document affects the availability, durability, reliability, safety, efficiency and cost-effectiveness of production processes, materials, refrigerants, servicing and disposal infrastructures, components & systems is rated in this indicator.

NR - Awareness & Psychology: This indicator investigates if and how information and awareness-raising campaigns, Business-to-Consumer and Government-to-Consumer elements are strengthened to address misconceptions about natural refrigerants within the industry and the wider public.

NR - Economy & Costs: Direct support for non-fluorinated gases is one of the most important measures to accelerate the deployment of natural refrigerant solutions. If incentive-based (taxes, subsidies, marketable trading permits, funding/grants) or command-and-control means (standards) to reduce price gaps are used is investigated in this indicator.

VS - Economy (dynamic efficiency): This indicator refers to how incentives for enhanced innovation potential, and for balancing short run concerns (static efficiency) with concerns in the long run (R&D) are set for an increased resilience (resistance / adaptation) to economic shocks in the HVAC&R industry.

VS - Environment (ecological safety): The dominant element in this indicator is the environmental leadership shown in the policy initiative as regards environmental protection within the EU and for the EU compared to other world regions. More concretely, it talks about achieving the country's and/or the EU's renewable energy, energy savings and emissions targets.

VS - Social (fairness): The indicator looks at the burden-sharing between market actors and citizens within the EU, and the fairness towards non-EU and developing countries in fully implementing the legislation.

VS - Leadership: How ambitious in general is the policy initiative as a combination of economic, social and environmental concerns, which timeframe (short, medium, long term) does it set for change and what is its overall leadership potential?

EE - Access: This refers to whether a clear and unambiguous language is used in the policy document, its targeted application fields, as well as the collaboration with and active communication towards addressees of the policy before drafting the initiative (consultations, call for input, meetings). Also rated are the ease of accessing and understanding the information by the target group.

EE - Implementation: This refers to guidance and support provided in transposing the legislation into national law, the responsiveness of national governments and the industry to the legislation, as well as the ease of monitoring. Most importantly, it also includes an analysis of whether mandatory reporting requirements exists.

EE - Compliance: Whether suitable compliance mechanisms are in place, incentives set for the addressees to comply (moral hazards, adverse selection), or penalties designed to encourage compliance, are rated in this indicator.

EE - Flexibility: Is there a fixed review period and/or constant update of legislation or individual elements foreseen in the original document if new (scientific, industry) information becomes available? This indicator also analyses if flexible and effective tools for Member State integration are in place.

EU POLICIES: MAC DIRECTIVE & F-GAS REGULATION

MAC DIRECTIVE

The MAC Directive has set a precedent in setting a maximum allowable Global Warming Potential (GWP calculated over 100 years) value of below 150 that refrigerants used in mobile air conditioning (MAC) may not surpass. It has driven the interest in development and optimisation of MAC systems and components suitable for use with low-GWP natural refrigerant CO_2 and more recently hydrocarbons, and also contributed to the adoption of natural refrigerants in other, mobile and stationary, applications.

F-GAS REGULATION

The existing EU Regulation on fluorinated gases relies primarily on containment and recovery measures to prevent hydrofluorocarbon (HFC) emissions from the HVAC&R sector. However, part of the industry is preparing for more rigorous measures in the future: current discussions in the context of a likely revision of the Regulation indicate that more action is needed to reduce f-gas emissions in the EU if the bloc is to achieve its long-term greenhouse gas emission targets.

EU POLICIES: MAC DIRECTIVE & F-GAS REGULATION

MOBILE AIR CONDITIONING (MAC) DIRECTIVE

Adopted in 2006, the MAC Directive (Directive 2006/40/EC relating to emissions from air-conditioning systems in motor vehicles) bans MAC systems working with fluorinated GHGs with a Global Warming Potential (GWP) higher than 150 from 2011 for new types of vehicles, and for all new vehicles as of 2017. The ban therefore covers the most commonly used refrigerant, HFC134a (GWP = 1,430).

The mechanism to implement the Directive is the type approval procedure at national level, by which car manufacturers need to homologate their vehicles before they can be put on the market. With the automotive sector seeking a global solution for their MACs, EU manufacturers have announced that they will be using a next generation chemical refrigerant with low-GWP to meet the requirements of the Directive. These included German carmakers, which had initially committed to using natural refrigerant CO_2.

Nonetheless, new MACs with low-GWP refrigerant are still to make their debut on the EU market due to lack of availability of the new chemical substance, with one carmaker already reported to have acquired compliance exemption by a national type approval authority – a development that might contaminate overall effectiveness of the Directive.

Looking at the future, with the ban in place, and flammability as a property of refrigerants gaining increasing acceptance, hydrocarbon natural refrigerant which are widely used worldwide in the MAC servicing sector, could also be one of the future solutions selected for new MACs by carmakers. Natural refrigerant CO_2 is also seen as a good candidate to cover both heating and cooling needs for electric vehicles, which are to gain market share in the EU and worldwide.

Overall, the Directive has had a positive impact on natural refrigerants, by enabling development of CO_2 technology and components not only for passenger vehicles but also for other applications currently not in the scope of the Directive, including buses and trains. It has also benefited the know-how in natural refrigerant CO_2 for stationary applications.

The MAC Directive has set a precedent in restricting the GWP allowable for refrigerants in a specific application. The impact of the Directive spans wider than the EU, with US authorities also considering a ban on the use of high GWP HFC134a in motor vehicle air conditioning systems. California is also proposing to incentivise the use of low-GWP refrigerants in Mobile Air Conditioning (MAC) systems of new vehicles.

F-GAS REGULATION

To address the issue of emissions related to the use of HFCs, the European Union has adopted the F-Gas Regulation (Regulation No 842/2006 on certain fluorinated greenhouse gases). In place since June 2006 in the EU, the overall objective of the F-Gas Regulation is to prevent and thereby reduce leakages of high-global warming f-gases such as hydrofluorocarbons (HFCs). The regulation's main impact is on systems containing 3 kg or more refrigerant, to which regular leakage checks and record keeping apply, in addition to end-of-life and repair requirements. Owners and operators of such systems bear additional costs to meet the various requirements, while on the other hand natural refrigerant equipment is out of the scope of the Regulation and its requirements.

"The application and enforcement of this Regulation should spur technological innovation by encouraging continued development of alternative technologies and transition to already existing technologies that are more environmentally friendly", reads the text of the Regulation. Although not placing any use bans on the HVAC&R sector, the Regulation is seen as an indication of stricter requirements in the future, with several manufacturers of stationary equipment carrying out R&D and investing in natural refrigerants to insure against future strengthening of the Regulation and potential use and marketing restrictions. The Regulation has also inspired natural refrigerant training initiatives that are being developed in parallel to f-gas training courses, together with private initiatives to phase out high GWP gases by supermarket chains (see UK and Switzerland) and global consumer goods end users (CGF[1], Refrigerants Naturally!).

Future developments with this Regulation is crucial for the natural refrigerant industry, with the EU executive body, the European Commission, currently considering a revision that is likely to result in strengthened requirements. A first report assessing the effectiveness of the Regulation suggests that more action is required in addressing HFC emissions, if the EU is to meet its long-term emissions reduction targets (European Commission, 2011). The same report considers different options for achieving additional reductions of f-gas emissions in the EU, including use and marketing prohibitions for new equipment and products, voluntary environmental agreements at Community level, a tax on sales of HFCs and pre-charged equipment, stricter containment and recovery measures etc. Although currently too early to assess what could be the preferred approach for achieving additional HFC emissions reductions in Europe, it may be expected that requirements be tightened, further bridging the capital cost gap between traditional and natural refrigerant technologies.

1 Consumer Goods Forum

EU POLICIES: HCFC PHASE-OUT, ECODESIGN & ECOLABEL

HCFC PHASE-OUT IN THE EU

The recast of the EU Regulation on ozone depleting substances in 2009 accelerated the HCFC phase out schedule by placing a complete ban on using HCFCs (both "virgin" or "recycled") by 2015, enhancing therefore the urgency to replace HCFC equipment/plants. Some entities seek to leap-frog HFCs, especially in equipment with a long lifetime and big refrigerant inventories.

ECODESIGN FOR AIR CONDITIONERS

With Ecodesign aimed at improving overall environmental performance of products, the Ecodesign Regulation for room air conditioners establishes a 10% incentive in terms of lowered minimum energy efficiency requirements for products using refrigerants with GWP ≤150. The low-GWP bonus formally recognises the importance of refrigerant emissions in the EU and opens the way for including similar provisions in Ecodesign regulations concerning other refrigerant using product groups.

EU ECOLABEL

Products that are awarded the voluntary European Ecolabel allow users to identify products and services that are kinder to the environment. Minimum energy efficiency requirements for awarding the heat pump ecolabel are easier to meet for products that use a refrigerant with GWP ≤ 150. Further Ecolabels for hydronic central heating generators, air conditioning, water heating, refrigerators and buildings will be developed by 2015.

EU POLICIES: HCFC PHASE-OUT, ECODESIGN & ECOLABEL

HCFC PHASE-OUT IN THE EU

Regulation No 1005/2009 on substances that deplete the ozone layer is the legal instrument in the European Union that sets out the HCFC phase-out schedule in its member countries. Accordingly, the use of HCFCs in new equipment has been banned in Europe since early 2000. Since January 2010 virgin HCFCs have been banned for maintaining & servicing of existing systems while at the same time a total ban on supply of virgin HCFCs took effect. Reclaimed or recycled HCFCs can be used to service or maintain equipment until 2015. After this date, the European Union does not allow the use of ozone depleting substances any more, which means that plants/equipment with HCFCs can only continue running for as long as they do not need topping up, and after this point they would either need to stop operating or be replaced.

Many users with multiple systems have planned a replacement strategy to conserve their stock of HCFC-22 refrigerant, setting priorities for which system to replace or convert first by considering the age of the plant, likelihood of leakage and ease of conversion (RTOC, 2010).

Implementing retrofits and replacements of HCFC industrial refrigeration equipment for example offers replacement options ranging from hydrofluorocarbons (HFCs) to natural refrigerants like ammonia and carbon dioxide. With the complete HCFC phase out coming up in 2015, some companies are proposing natural refrigerant solutions as long term replacements to their customers. Of course HFCs are also often proposed as the replacement technologies in many applications. Nonetheless, the recast regulation, which brought forward the HCFC phase out in the EU, has been one of the reasons why several companies have been looking into natural refrigerants as future proof replacements, developing products, enhancing safety, reliability and reducing their costs. In combination with the fact that in the meantime (2006) the F-Gas regulation was introduced, the recast regulation has enhanced the urgency to replace HCFC equipment/plants, with forward-looking entities seeking to leap-frog HFCs, especially in applications for which equipment has a long lifetime and where HCFCs are still widely in use (e.g. industrial refrigeration plant stock).

The EU legislation has not only been effective in controlling ozone depleting substances but also acted as a driver for the development of innovative technologies (eg chillers with ammonia charge as low as 0,1kg per kW capacity).

ECODESIGN FOR AIR CONDITIONERS

Ecodesign rules consider the environmental impact of energy-using products throughout their entire life-cycle and products not meeting certain requirements will not be allowed on the EU market. Under the life-cycle approach, direct emissions from the refrigerant are also taken into account. However, currently the existing regulations and those under development mainly focus on efficiency.

An exception is a new Ecodesign regulation for room air conditioners (Commission Regulation implementing Directive 2009/125/EC), which has set a precedent in recognising the contribution of refrigerants in the environmental footprint of products by providing a bonus in energy efficiency requirements for products using refrigerants with a Global Warming Potential (GWP) below 150. However, the measure is an incentive but not a requirement and has somewhat poor visibility, as it is not reflected on the corresponding energy label.

Similar opportunities for introducing low-GWP bonuses could arise for several other refrigerant containing product categories that are currently being discussed under

Ecodesign, including commercial & professional refrigeration, boilers and water heaters and tertiary air conditioning. Overall there is a big potential for advantageous requirements for naturals refrigerants in Ecodesign regulations currently being devised or when regulations are reviewed (typically within 5 years after entry into force).

EU ECOLABEL

The EU Ecolabel is a voluntary scheme, established in 1992 (and revised in 2009) to encourage businesses to market products and services that are kinder to the environment. Products and services awarded the Ecolabel carry the flower logo, allowing consumers - including public and private purchasers - to identify them easily, while producers find that it gives them a competitive advantage.

Today, the EU Ecolabel covers a wide range of products and services, with further groups being continuously added. The environmental criteria behind the EU Ecolabel are agreed at European level based on life-cycle analysis and the label itself is only awarded after verification that the product meets these environmental and performance standards.

HVAC&R related product groups for which award criteria have been established include heat pumps, including both electric and gas heat-pumps with a maximum heating capacity of 100 kW, but not heat pumps that can only provide domestic hot water for sanitary use: current criteria for awarding the heat pump ecolabel are valid until 31 December 2011. With regards to the refrigerant used, the decision requires that its global warming potential (GWP) must not exceed GWP value > 2,000 over a 100 year period. If the refrigerant has a GWP of less than 150 then the minimum requirements of the coefficient of performance (COP) and primary energy ratio (PER) in heating mode and the energy efficiency ratio (EER) in cooling mode shall be reduced by 15%.

Other HVAC&R product groups for which EU Ecolabel award criteria are currently under development/revision include an EU Ecolabel for:

- Buildings: A pilot study on developing EU Ecolabel and Green Public Procurement (GPP) criteria for "Buildings" is being carried out. This could be an EU wide equivalent to the UK BREEAM scheme, which sets refrigerant requirements.
- Hydronic central heating generators (up to 400 kW): EU Ecolabel and Green Public Procurement (GPP) criteria (efficiency, greenhouse gas emissions, refrigerant etc) for hydronic central heating generators (including heat pumps) are being developed. There will be one label for all different types of generators, with oil generators having a disadvantage (high emissions) and heat pumps on the other hand having an advantage in meeting the award requirements. GWP refrigerant requirements could in theory be included, though in practice it seems not likely and will depend on stakeholder input received.
- Refrigerators: with hydrocarbons being the standard there is a discussion to lower GWP limit below the previous value of 15.

In the future (2011-2015) the development of EU Ecolabels for the following HVAC&R related product groups are considered as priorities:

- Heating system (room)
- Water heating system
- Air conditioning

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Supermarket customers take for granted that product will be fresh, milk and meats at the proper temperature and frozen foods maintained perfectly frozen. With CO_2 flow control products, be assured your refrigeration systems operate reliably and efficiently while being constantly monitored by state of the art digital controls. High pressure CO_2 systems need heavy duty, ultra reliable components and supermarket owners demand dependable, trouble free systems with economical life-cycle costs and lowest possible carbon footprint. The Green Performance delivered by products are both in transcritical and subcritical modes.

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NATIONAL POLICIES: LEADERS, FOLLOWERS & LAGGARDS

Besides the European Union level, individual Member States have set ambitious targets to either phase out HFCs and/or promote natural refrigerants directly. At the other end of the spectrum, some national rules continue to pose a major hurdle for the NR industry, due to inappropriate charge restrictions or system bans. The following provides just a glimpse of three countries – 1 leader, 1 follower and 1 laggard in the field of natural refrigerants – with different approaches to a natural refrigerants market uptake.

DENMARK

Denmark has in place a combination of measures enabling a transition to natural refrigerants: Bans on all HFC uses except for applications with refrigerant charge between 150g and 10kg (Statutory Order no. 552 of 2 July 2002 governing fluorinated greenhouse gases); and Taxation of f-gases at €20/tCO_2eq (Consolidated Act No. 208 of 22 March 2001 on tax on certain ozone layer depleting substances and certain greenhouse gases) administered by the Danish tax authorities (SKAT). The tax act levies a green tax on the import of fluorinated greenhouse gases, to be paid to the Danish Government. The tax on industrial greenhouse gases is differentiated: the gases with the greatest impact on climate are subject to the highest tax level, with a tax level in 2011 set at about €17.5/kg for R134a and €50.7/kg for R404A. The HFC tax is repaid when products containing HFCs are exported. A country where stricter than the EU-wide minimum requirements regarding f-gases are in place, Denmark has seen two main trends regarding f-gases: 1) A more or less steady decline in imports of HFCs to Denmark, since the peak in 1998; and 2) overall f-gas emissions in decline.

The result for NR: The ban has been the main driver explaining the fast growth in market uptake of for example commercial refrigeration systems running on natural refrigerants in Denmark. The main HFC-free refrigerants in use in Denmark are CO_2 for supermarkets (see p.56), hydrocarbons for commercial refrigeration plug in cabinets and domestic refrigerators/freezers, ammonia for industrial refrigeration, as well as ammonia and hydrocarbons but also water for chillers.

GERMANY

Germany's initiatives beyond the F-Gas Regulation, include projects supported under the National Climate Initiative (NCI) and the International Climate Initiative (ICI), funding for R&D and pilot projects related to the use of halogen-free substances, the promotional programme for climate protection measures in the field of commercial refrigeration and the German Refrigeration Award that has so far recognised several HVAC&R natural refrigerant products.

The National Climate Initiative, in particular, is supporting investment in more efficient and innovative technologies by the German industry. One example is the Climate Protection Incentive Programme for commercial refrigeration systems, which seeks to reap the potential for savings in costs, energy and CO_2 emissions by employing the technologies available on the market. Since 2009, the Federal Office of Economics and Export Control (BAFA) has deployed this programme in two areas: 1) the refurbishment of existing refrigeration plants that have an annual energy consumption of at least 150,000 kWh and potential savings of at least 35% to be gained through using more efficient components and systems; and 2) the construction of new units with an annual energy consumption of at least 100,000 kWh based on exclusive use of natural refrigerants, such as ammonia (NH_3), carbon dioxide (CO_2) or propane. In 2010, BAFA granted authorisation for 204 plants, disbursed grants for net investment costs to the value of 10,177 million euros and

approved funding for an additional €7.893 million. As a result, 45% average energy savings have been achieved by the subsidised plants.

The result for NR: The funding programme has provided some stimulus for the CO_2 market in the German retail sector, as confirmed by several manufacturers. However, relevant players admit that funding opportunities are somewhat modest and only retailers have the option to apply for it, thus providing no strong incentive to suppliers. Also, at the international level, the International Climate Initiative (ICI) has been supporting projects in developing countries, emerging economies and in the transition countries since 2008. Funded projects include HVAC&R production plant conversions to natural refrigerants, or facilitating the development and introduction of standards for natural refrigerants.

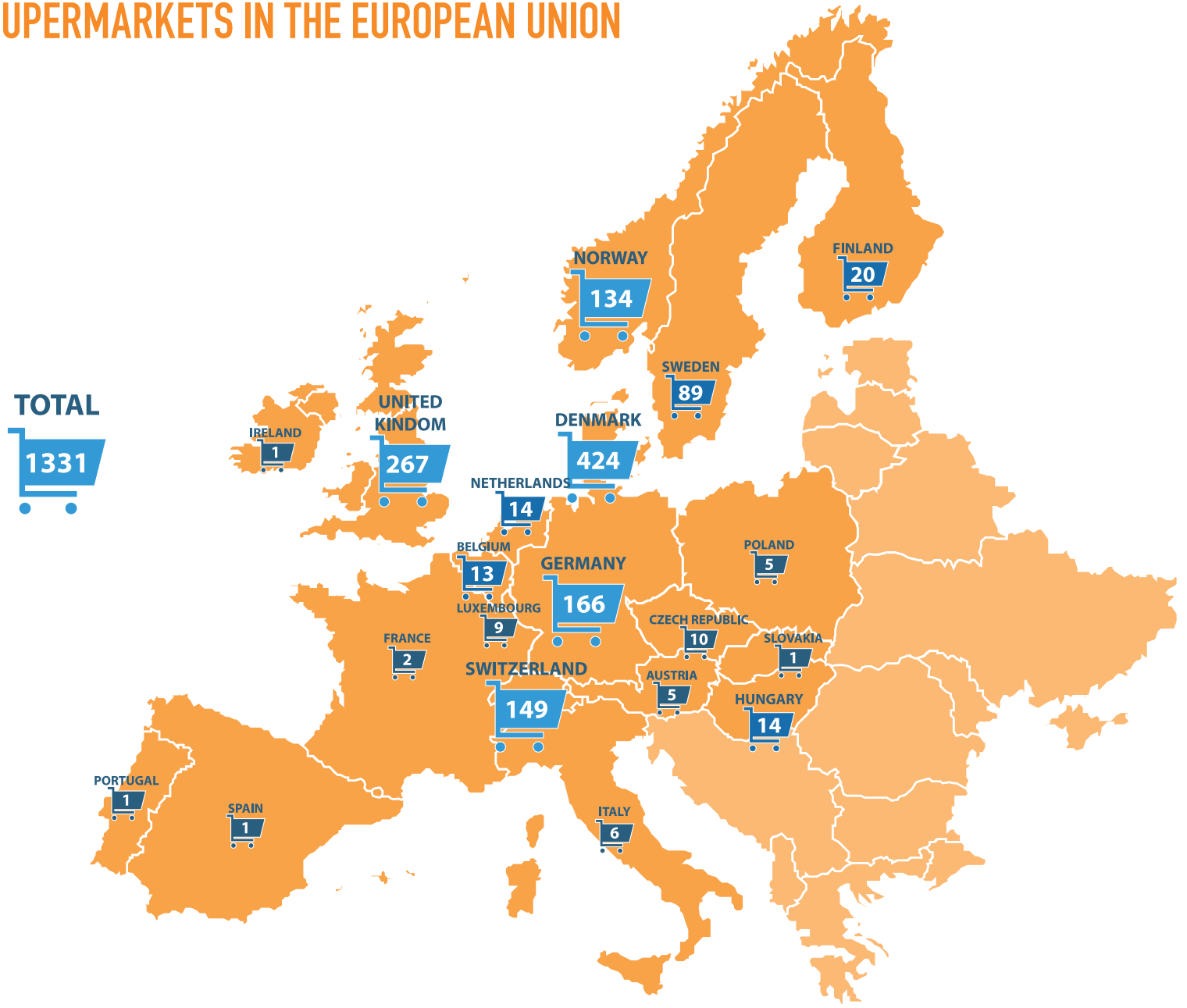
FRANCE

A French decree forbids the use of flammable refrigerants including hydrocarbon refrigerants in premises with access to the public such as supermarkets (Arrêté du 14 février 2000 — Etablissements recevant du Public, Article CH 35: Production, transport et utilisation du froid). The same decree allows the use of ammonia in premises with public access, only if the following conditions are met simultaneously: 1) it is used in an indirect system; 2) the ammonia refrigeration system is located in a separate machine room; and 3) the total amount of ammonia in a facility is limited to 150kg. This seems to have encouraged the continuation of HCFC use in the country at a larger share than other countries in Europe. However, operators of facilities with public access will soon be facing the 2015 deadline whereby they will not be able to top up their refrigeration systems with reclaimed or recycled HCFCs anymore and will soon after be expected to shift away from their use.

The result for NR: While regulatory restrictions render the use of traditional direct expansion ammonia systems in France practically very difficult, indirect ammonia systems with CO_2 secondary refrigerant, could satisfy the regulatory conditions specified in French regulations: ammonia is restricted in a plant room, the system is an indirect one, and the ammonia charge can be limited to 50-100 kg. However, with hydrocarbons completely out of the picture, and limitations on the use of ammonia, HFCs are expected to be widely phased in as HCFC replacements.

CO_2 TRANSCRITICAL SUPERMARKETS IN THE EUROPEAN UNION

DATA BY COUNTRY



CO_2 TRANSCRITICAL SUPERMARKETS IN THE EUROPEAN UNION

COUNTRY	CO_2 TC SUPERMARKETS
Austria	5
Belgium	13
Czech Republic	10
Denmark	424
Finland	20
France	2
Germany	166
Hungary	14
Ireland	1
Luxembourg	9
Italy	6
Norway	134
Poland	5
Portugal	1
Slovakia	1
Spain	1
Sweden	89
Switzerland	149
The Netherlands	14
UK	267
TOTAL	1331

The following companies provided direct input for the *Guide: Natural Refrigerants Market Growth for Europe*

SUPERMARKETS

Auchan *(France)*
Coop *(Norway)*
Booths *(UK)*
Carrefour *(France)*
Casino *(France)*
The Cooperative *(UK)*
Delhaize *(Belgium)*
Kesko Food *(Finland)*
Migros *(Switzerland)*
SONAE *(Portugal)*
Spar *(Switzerland)*

SUPPLIERS

Advansor
Alpiq
Carrier
Cool-Tec SA
enEX
Epta
Frigo-Consulting
Green&Cool
Hauser
Huurre
Knudsen Køling
Qplan
Sabcobel
SCM Frigo
Sabcolux
Space Engineering Services Ltd

ASSOCIATIONS

AKB – *Authorized Refrigeration Installers Association (Denmark)*

NVKL – *Association of Refrigeration Engineering & Air Treatmant Companies (Netherlands)*

VKE – *Refrigeration and HVAC Association (Norway)*

FREA – *Refrigeration Enterprises Association (Finland)*

CO_2 TRANSCRITICAL SUPERMARKETS

In 2002 the first supermarket CO_2 transcritical (TC) system was installed in Coop Lestans, Italy. Since then, Europe has become the unrivaled technology and adoption leader for HFC-free commercial refrigeration systems. By early 2012, industry experts estimated that around 1,200 food retail stores were already using CO_2 transcritical commercial refrigeration systems in the 27 EU Member States. This was in addition to the thousands of CO_2 cascade systems deploying carbon dioxide in subcritical state with another refrigerant that were operating successfully in Europe and beyond by that time. However, while an overall ballpark figure of 1000-1500 CO_2 TC stores was assumed to be in the range of industry expectations, no single report or publication had ever attempted to list and track installations by EU Member State. This was despite the fact that a more precise figure would be urgently needed by both technology leaders and legislators to quantify the future market potential of non-fluorinated gases, based on present figures and regional variation in the speed of market adoption.

From March to November 2011, shecco conducted detailed research among all major European supermarket chains, refrigeration system manufacturers and component suppliers to get as close as possible to the exact figure for CO_2 transcritical supermarket installations. 16 food retail chains, 14 system suppliers and component providers and 4 industry associations gave direct feedback regarding the number of installed systems, in addition to an analysis of available third party sources. In total, 106 supermarket chains, 34 system manufacturers, and 64 third parties - industry associations and not-for-profit organisations - were contacted.

THE LEADERS

When looking at the CO_2 transcritical supermarket map, four countries show significantly higher numbers of R744 installations than the others. Denmark (424), Germany (166), Switzerland (149), and the UK (267) have used very different tool sets combining voluntary standards, restrictions on refrigerant charges, taxation and industry initiatives. The following is a summary of each of these four CO_2 TC leaders:

DENMARK

Up to 2/3 of all Danish supermarkets are already running with CO_2 TC systems today. This is remarkable, given that the gradual replacement of old systems will continue into the near future, and that CO_2 cascade systems also have their market share. Today, Denmark is considered a pioneer and role model when it comes to legislating high global warming potential (GWP) refrigerants. Danish policy is stricter than EU policy and largely explains the flourishing CO_2 transcritical commercial refrigeration market.

Danish regulations, by and large prohibit the use of HFC gases and ozone depleting substances as refrigerants (see policy section). Whilst charges between 150 g and 10 kg HFC per circuit are permitted, as well as factory assembled heat recovery units with less than 50 kg, since 2007 all other new refrigeration systems with charges above 10 kg have been prohibited.

Complementing the HFC ban, in 2001 Denmark introduced a tax on the imports of bulk HFCs. The tax is 150 Dkr (approximately €20) per tCO_2eq. Moreover, to promote the spread of natural refrigerants, the Danish Environmental Protection Agency has set up a Knowledge Centre for HFC-free Refrigeration.

Denmark's success in making the use of f-gases financially and technically prohibitive in food retailing within the shortest timeframe is lauded overseas in discussions on restricting the use of hydrofluorocarbons.

GERMANY

The buoyant German market for CO_2 transcritical supermarket installations is largely thanks to an incentive scheme for commercial refrigeration using natural refrigerants run by the Federal Ministry for Environment (BMU). As part of the "Integrated Energy and Climate Protection Programme", at the end of 2008 the German Government instituted a "Climate Protection Incentive Programme for commercial refrigeration plants". This programme covers 25% of the net investment cost for new installations with a minimum energy consumption of 150,000 kWh per year using natural refrigerants. Retrofits of existing systems are also eligible to receive 25% of net investment costs, but must undergo an independent review to prove energy efficiency savings of 35% as a result of the new refrigeration system. Bonus funding is available if the natural refrigerant system is non-electrically powered, or if the waste heat from the refrigeration systems is recovered. The incentive scheme applies to food retail chains.

Retrofits of existing systems that do not use natural refrigerants but still operate with conventional fluids will be supported by only 15% of net investment costs, provided the system is more energy-efficient after.

SWITZERLAND

In November 2004 the first CO_2 direct expansion refrigeration system was installed in a Swiss hypermarket in Wettingen. Since then several supermarket chains have made the switch to CO_2 refrigeration systems, including leading retail chains Migros and Coop. The adoption of CO_2 transcritical installations in Switzerland has been incentivised by a mix of the voluntary "Minergie-Label" and HFC regulation.

The Minergie-Label is a voluntary standard, launched in

2007, by the Swiss Confederation, the Swiss Cantons and the Principality of Lichtenstein. It mandates proof of energy performance of heating, hot water, ventilation, refrigeration and air conditioning systems. For open cooling shelves a maximum energy consumption of 4 MWh per metre is stipulated. A widely accepted trademark for new and refurbished buildings Minergie. Leading retail chains Migros and Coop have announced that they will only build stores complying with the Minergie standard.

Since 2004 "substances stable in the air", such as HFCs have been tightly regulated in Switzerland, making alternative refrigerants such as CO_2 attractive as cooling solutions. The HFC regulation is contained in the Ordinance on Risk Reduction related to Chemical Products (ORRChem) and encompasses licensing, reporting, leak checks, servicing and end-of-life requirements for equipment containing more than 3kg of such refrigerants.

UK

Unlike Denmark and Switzerland, the UK does not tax or regulate high GWP refrigerants. However, CO_2 transcritical refrigeration in supermarkets has rapidly been gaining ground. The first UK system was installed in 2006 in Swansea in a Tesco supermarkets. Since then the number of installations has grown steadily, with over 200 systems now operational. UK retailers have led the adoption of R744 refrigeration systems, and are ahead of many of their UK counterparts. UK climate change regulation, preparation for upcoming legislation, and NGO pressure have likely incentivised investments in CO_2 refrigeration.

UK climate change legislation includes the 2001 Climate Change Levy (CCL) aimed at encouraging energy efficiency and reduced greenhouse gas (GHG) emissions; and the 2008 Climate Change Act, which sets a target for the UK to reduce carbon emissions to 80% below 1990 levels by 2050. Both encourage investments in climate friendly, energy saving refrigeration technology. In addition momentum is growing in the UK for HFC phase out or taxation. In 2010 a "Hydrofluorocarbon Limitation Bill" was launched. It may be expected that the UK will introduce stricter f-gases regulations, which will provide an impetus for a faster uptake of natural refrigerants in the country.

In addition the Enhanced Capital Allowances (ECA) provide businesses with enhanced tax relief for investments in equipment that meets published energy-saving criteria. There is a predetermined list of products (including commercial service cabinets and compressors) for which if installed, a business could qualify for receiving the allowance. Products that may be included in the ECA list have to meet certain criteria as prescribed by "The Energy Technology Criteria List" (ETCL).

Finally, the CRC Energy Efficiency Scheme (previously known as the Carbon Reduction Commitment) mandates carbon emissions reporting for all organisations using more than 6,000 MWh per year, equivalent to and electricity bill of around £500,000 (€600,000). As from 2012 organisations covered by the scheme will be required to purchase 'allowances' from the Government each year to cover their emissions from the previous years. The money raised by the sale of allowances will be cycled back to CRC participants.

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- Low cost of maintenance • Future-proof solution

ADVANSOR™

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Advansor is an internationally-leading manufacturer of sustainable refrigeration: for supermarkets, industrial refrigeration, power plants, food processing industry, chemical industry and air conditioning of office spaces – with CO_2 as the only refrigerant.

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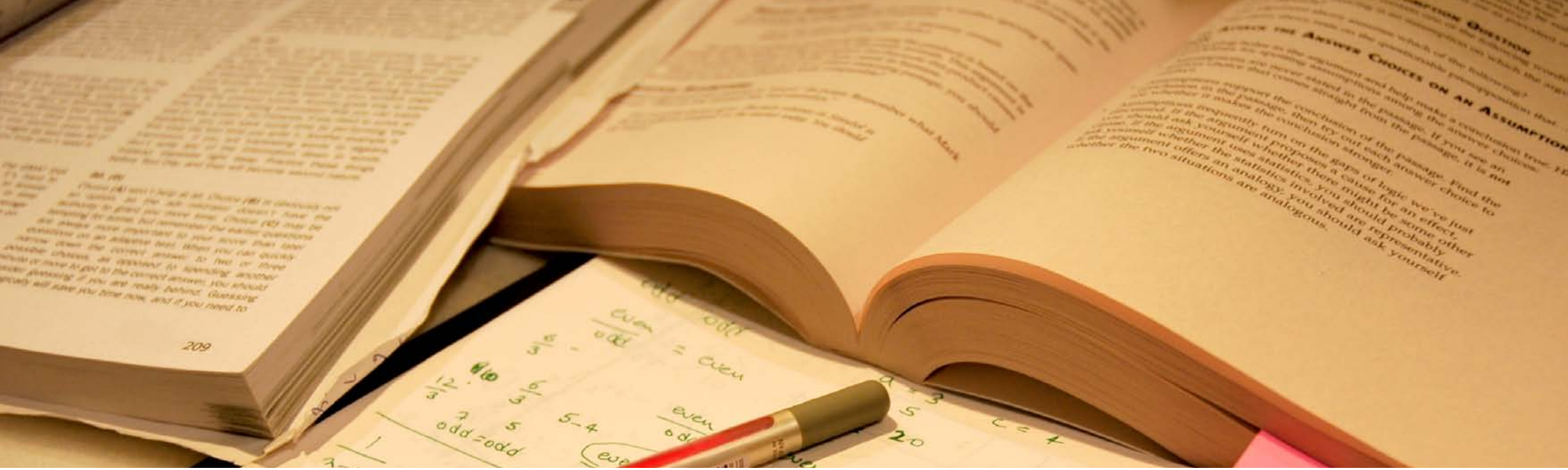
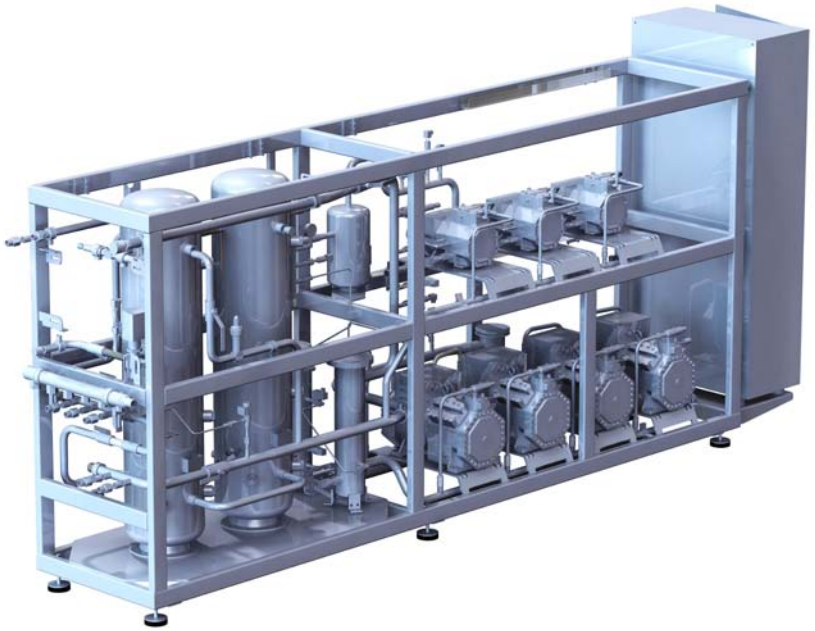


CASE STUDIES

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 refrigerants-based systems, this section presents a selection of outstanding examples, covering residential, commercial and industrial heating, air-conditioning and refrigeration solutions.

Included are examples from Europe-based suppliers: hydrocarbon chillers in a Danish hospital, CO_2-based domestic heat pumps from France, low-charge ammonia chillers and CO_2 quick freezing solutions in the fish processing industry, high-efficiency R744 compressors, 400 successful CO_2 supermarket installations, and more.

500 EXPERIENCES WITH CO_2 IN SUPERMARKETS



ABOUT THE COMPANY

Advansor is a leading OEM manufacturer of sustainable thermal systems for the production of heating and cooling in supermarkets, cold stores and freezing facilities with CO_2 as the refrigerant.

More information at:
info@advansor.dk and www.advansor.dk

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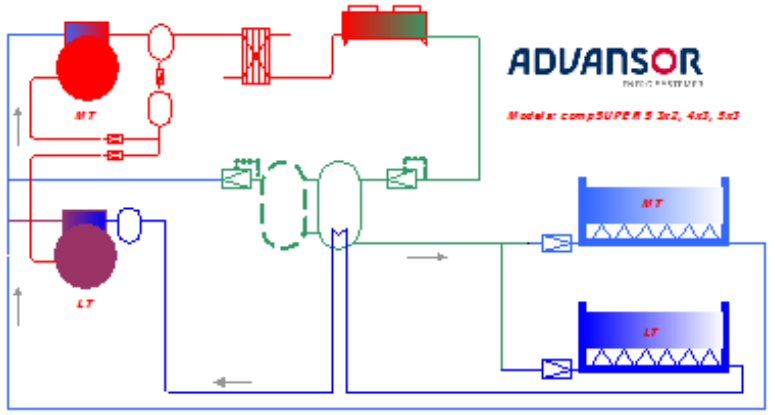
INTRODUCTION

Since 2006, European retailers have been making the fast transition from HFC to the better refrigerant CO_2 in their supermarkets. Denmark came to be the pioneering country with CO_2 taxation and a ban on HFC charges above 10 kg, meaning there was no other choice for the retailers than to move to natural refrigeration solutions. For these reasons, Denmark has a higher penetration rate of CO_2 systems than any other country in the world. During 2007 and 2008 other European retailers introduced their first trial stores and CO_2 has been an ever growing success and widely considered the future choice for supermarkets.

This case study takes a look at the regulatory instruments and technical benefits behind the success of rolling out CO_2 in approx 1.500 European supermarkets.

ABOUT THE SYSTEM

The standard transition pattern (trend) seen, is movement from HFC to cascades of HFC/CO_2 and then to pure CO_2 booster systems in the final step. The CO_2 booster principle is a lot more simple, it looks almost like the normal HFC unit, it is proven more efficient in most of Europe and it is proven more reliable than the cascade systems.



The preferred system in the retail industry is dual temperature CO_2 DX Booster systems. Because CO_2 is highly suitable for heat recovery to tap water and to building heating such integrated solutions are commonly applied to improve the overall energy efficiency of the building even further.

The Advansor solution contains only one refrigerant, CO_2, and offers obvious environmental benefits as well as energy savings.

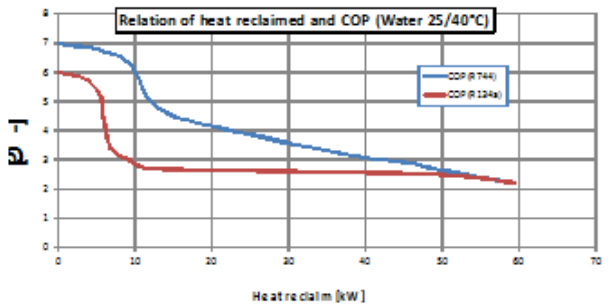
RESULTS

Energy Efficiency

Results of cycle simulation using DRY hourly data show that a simple CO_2 booster system offers superior performance to cascade systems in colder regions of Europe and comparable energy consumption even in Southern Europe. The results comply very well with field measurements. Furthermore, the results are interesting because the CO_2 process below can be improved by various means, additionally 5-10% in the warmer climates.

	Energy Index to CO2 DX Booster	
CITY	**HFC WITH SECONDARY'S**	**CASCADE (HFC134A / CO_2)**
Stockholm (Sweden)	134	120
Oslo (Norway)	134	120
Paris (France)	127	113
Lyon (France)	123	109
Marseille (France)	117	103
Barcelona (Spain)	116	103

Heat recovery as mentioned above is more beneficial with CO_2 than for any other refrigerant because the hot gas temperature is warmer and the energy density is higher. Furthermore, the heat extraction can be controlled much better to match the building online capacity demand. Recent Swiss field investigations comparing R134a and CO_2 report up to 40% increase of heat recovered at normalized refrigeration power input.



SUMMARY

Summary overview of incentives for retailers refrigerant transition to CO_2 in different countries:

- Denmark: HFC taxation, HFC ban, Energy savings
- Norway : HFC taxation, Energy savings
- Sweden and Finland: Energy savings
- Switzerland: Rules and Energy savings
- UK: Carbon footprint reduction schemes

All through Europe, CO_2 has been implemented safely and reliably as well as proving its benefit for the environment and energy reductions.

ADVANSOR by HILL PHOENIX

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 trans-critical type was commissioned in 1999. Today, Dorin produces more than 70,000 compressors per year.

More information at:
http://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 many kind of application. The compressor represents one of the most critical components in CO_2 transcritical applications. In designing CO_2 compressors several challenges have to be overcome, mainly linked to the refrigerant thermodynamic characteristics, like high discharge temperatures (up to 200°C), which impacts on both oil temperature and refrigerant suction temperature and density. This affects lubrication as well as the compressor volumetric and isentropic efficiency.

Different design concepts impact on compressor heat transfer and dissipation. Improving discharge gas heat rejection it is possible to increase both compressor reliability and efficiency. The main results of several design experiments are summarised and described below.

ABOUT THE SYSTEM

A new generation of CO_2 transcritical compressors has been developed, with displacements ranging from 1.1 m^3/h to 26.6 m^3/h and motor power ranging from 1.5 hp to 40 hp. The newly developed compressor ranges (CD200, CD300, CD400) offer the largest choice in terms of available models, making it possible to realize installations of any size, from residential to commercial and industrial ones. Compressors are developed in semi-hermetic platforms with 2 and 4 cylinders. Compressors are able to operate in a very broad application envelope, with working pressures up to 150 bar; qualifcation life testing highlighted how robust the compressors are, able to work with differential pressures up to 120 bar and 200°C discharge temperatures.

The compressor model tested was CD1900H, 11.62 m^3/h, 20 hp. Due to the very high end of compression temperature, particular focus has been given to the heat rejection at the high pressure side of the compressor. Two main design experiments (A and B) were carried out and tested, shown in Figure 1 and Figure 2.

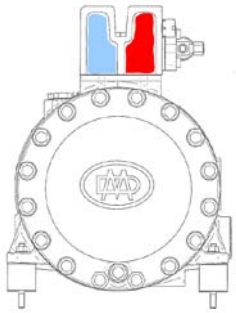

Figure 1: Design of experiment A

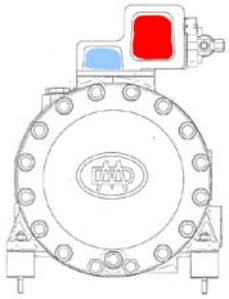

Figure 2: Design of experiment B

Concept B has the intention to thermally separate the head high pressure side (red) from the head low pressure side (blue) and the compressor body. By dissipating the heat to the ambient thanks to convection to surrounding atmosphere, this avoids or limits heat thermal conduction to the compressor body and, especially, to the oil sump.

RESULTS

Compressor model CD1900H was thoroughly tested in two concepts and was equipped with pressure and temperature sensors to monitor its behaviour and performances:

- A Coriolis mass flow meter was used to measure refrigerant flow and a Wattmeter has been used to measure compressor power consumption.
- A 68 cSt nominal viscosity oil (PAG) has been used as the lubricant.

The two concepts were tested in equivalent rating conditions and the main operational parameters were recorded and analyzed.

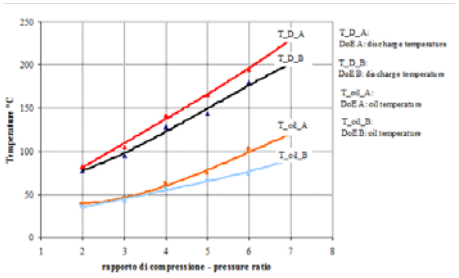

Figure 3: Discharge and oil temperatures for Design of Experiment A and B

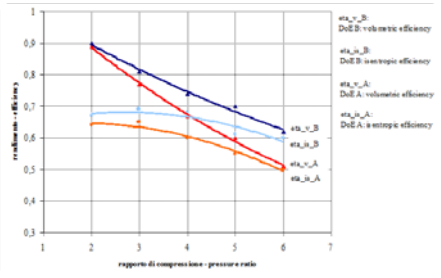

Figure 4: Volumetric and Isentropic efficiencies for Design of Experiments A and B

Experimental results are summarised and shown in figures 3 and 4.

Figure 3 highlights important aspects relating to compressor reliability. The design of experiment B brings about a consistent reduction of both end of compression and lubricant temperatures thanks to the aforementioned thermal heat dissipation. Therefore, design of experiment B is preferable as it leads to several advantages, for instance:

- lower end of compression temperature, leading to lower oil cracking risk
- lower lubricant temperature, leading to oil lubricity increase with consequent increase of compressor lifetime

Figure 4 offers a clear indication of why the design of experiment B is to be preferred, since it greatly out-performs the design of experiment A both in terms of volumetric and isentropic efficiencies.

CONCLUSIONS

As predicted, consistent benefits arise from the enhancement of the heat dissipation from the compressor high pressure side to the surrounding ambient, both in terms of reliability and performance.

A new transcritical CO_2 compressor generation is now available for many kinds of applications, featuring the technical advantages described in this case study.

QUICK FREEZING SALMONS AT NORDLAKS AS, STOKMARKNES, NORWAY

ABOUT THE COMPANY

Since its start in 1885, Johnson Controls has grown into a global leader in building efficiency, automotive experience, and power solutions. JCI is one of the leading companies of refrigeration and chiller solutions based on natural refrigerants. It offers products and services that optimize energy use and improve comfort and security.

More information at:
www.johnsoncontrols.com

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INTRODUCTION

In recent years the use of CO_2 as a refrigerant especially for freezing of food has increased all over the world. The benefit of lowering the temperature is faster freezing times. A 10 K lower freezing temperature gives 25% quicker freezing time, enabling a higher throughput on the same footprint using the same freezers. This is widely appreciated especially in the fishing industry and even more so onboard ships where space is critical. In this specific project the system is land based and the fish is produced in cages at sea. The lower freezing temperatures here give a quality product, which is appreciated by the end consumers.

ABOUT THE SYSTEM

The system installed has to fulfil following requirements:

- Freezing of whole salmon in IQF 1 (spiral freezer). Frozen product 4-6 metric tons per hour. Capacity required 600 kW at Te=-47˚C
- Freezing of salmon filets in portions in IQF 2 (spiral freezer). Frozen product 1,5-2 metric tons per hour. Capacity required 200 kW at Te=-47˚C
- Cold-store kept at -28˚C. Room volume 7800 m^3. 40 metric tons food stuff in and out per day. Capacity required 100 kW
- 3 refrigerated rooms at +2˚C and a total cooling requirement of 65 kW
- Heating of freezing area. Heating load calculated to 180 kW
- Floor heating of marshalling area and cold-store

During the installation a desire for hot tap water for washing came up

The provided solution is a cascade CO_2/NH_3 system with a total cooling capacity of 800 kW at -47˚C. The +2˚C rooms are cooled by a separate glycol heat exchanger in the ammonia system. Defrost is performed by using the fans.

The system has now been in operation for a couple of years and the customer said at a presentation in Norway that the company was a little bit sceptic in the beginning but now that it has proven to work he would not hesitate to take the journey again.

SOME FACTS ABOUT CASCADE VS. 2-STAGE AMMONIA

The cascade system is designed for Te/Tc = -47,5/42˚C. Tc CO_2 -7˚C and -12˚C for the high stage compressors

We have simulated a two-stage ammonia system for the same conditions with an open intercooler with a temperature at -12˚C

The results are as follows:

- 11 times larger swept volume on the low stage ammonia system
- 8% higher energy consumption

If we then assume the -47˚C in the IQF freezers and 100 meter return line, 10 bends and a circulation ratio of 2 and a pressure loss of 0,5 K we get:

- Two stage ammonia DN 300
- Cascade system DN 150

Since the heat capacity of ammonia is higher than CO_2 we get following liquid lines:

- Two stage ammonia DN 40
- Cascade system DN 65

Another advantage of the cascade system is that the ammonia high stage now only operates at pressures well above the ambient pressure and therefore there is no need for air purger and no water enters the system.

RESULTS

The experience with the plant shows that this concept is very reliable and high performing. When the IQF freezers are in operation there is only a temperature difference of 5 K between the room temperature and the evaporating CO_2.

The required swept volume is only about 10% of the comparable two-stage ammonia system on the low stage.

The return lines are remarkably smaller. The liquid lines are bigger but it makes only a negligible difference.

The customer Nordlaks AS are very happy with the performance of the system.

Johnson Controls

SMALL AMMONIA CHILLER COLD ROOM COOLING

ABOUT THE COMPANY

Since its start in 1885, Johnson Controls has grown into a global leader in building efficiency, automotive experience, and power solutions. JCI is one of the leading companies of refrigeration and chiller solutions based on natural refrigerants. It offers products and services that optimize energy use and improve comfort and security.

More information at:
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INTRODUCTION

Johnson Controls has built and supplied a small ammonia unit for keeping a storage cold for ready for sale products. The room temperature is +10°C

In Denmark the maximum charge when using HFC refrigerants is 10 kg. This could be interpreted as the reason for going ammonia. However, in this case the main reason for using ammonia is the company policy to reduce its carbon foot print and using natural refrigerants is one of the ways Novo Nordisk hopes to do that.

ABOUT THE SYSTEM

The high efficiency of ammonia helps to reduce the running cost of the system. The inverter insures that the compressor can adjust the capacity to the requirements at any time of day giving an optimal efficiency. The compressor furthermore has two unloaders allowing the load to become relatively low before the compressor is cut out.

As the final product is temperature sensitive the reliability of the chiller is very important to the customer. The design and the way the system works is regarded as so safe that the customer has decided only to install one unit instead of two.

The compressor is inverter driven which gives a very high efficiency especially in low load periods. The unit is placed on a roof which makes the installation very simple to access and it presents no problems if a new compressor needs to be installed in case of an unexpected break down.

The very top management of Novo Nordisk is focused on global warming as an important problem and therefore it has been decided to avoid the use of HFC refrigerants. The Global Warming Potential (GWP) values below used are the 20 year integration times as seen in a declaration.

GAS	REFERENCE	GWP
Carbon Dioxide		1
Methane	Other: GWP20	62
Nitrous Oxide	Other: GWP20	275
HFC-134a	Other: GWP20	3300
HCFC-22	Other: GWP20	4800
Other: HFC-407C	Other: GWP20	3605
Other: Propylene	Other: GWP20	3
Other: HFC-404A	Other: GWP20	5588
Other: HFC-507	Other: GWP20	5700
Other: Propane	Other: GWP20	3

Ammonia chillers are used in many places but the GWP is 0 and is therefore not reported in the table above.

RESULTS

Johnson Controls has built and supplied the customer an ammonia chiller for cooling propylene glycol that in turn cools a cold room for storage of ready for sale products.

The supplied unit is one of the biggest in this capacity range from about 45 kW to 160 kW. The design results in a minimal foot print for the unit. The low charge of the system is attractive in places where an unexpected release of refrigerant can cause problems with neighbours.

The customer Nordlaks AS is very happy with the performance of the system.

Johnson Controls

CHILLERS AND HEAT PUMPS BASED ON HYDROCARBON REFRIGERANTS INSTALLED AT AARHUS UNIVERSITY HOSPITAL SKEJBY

ABOUT THE COMPANY

Since its start in 1885, Johnson Controls has grown into a global leader in building efficiency, automotive experience, and power solutions. JCI is one of the leading companies of refrigeration and chiller solutions based on natural refrigerants. It offers products and services that optimize energy use and improve comfort and security.

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INTRODUCTION

Following the ban on the installation of new R22 systems and the ban on using virgin R22 from year 2000 in Denmark the government has introduced a maximum charge when it comes to HFC of 10 kg. Multiplexing systems using 10 kg or less are not allowed unless they can be proven to be more efficient than alternatives. Furthermore the government has introduced a taxation on HFC refrigerants based on the global warming potential (GWP) values for the individual refrigerants. The tax is collected at the importers point of sale.

ABOUT THE SYSTEM

In light of this ban and tax Aarhus University Hospital Skejby had to make a decision regarding their future chiller systems for cooling different locations aroud the hospital and also regarding the condensers of refrigeration systems in different hospital sectors and research labs.

	R600A	R600A	R744	R744
	40˚C/70˚C	40˚C/80˚C	40˚C/70˚C	40˚C/80˚C
COP heat	3,7	3,3	2,9	2,9
Assumptions	Te=5˚C	Te=5˚C	Te=5˚C	Te=5˚C
	Tc=68˚C	Tc=78˚C	Pc=110bar	Pc=110bar
	Sc=25K	Sc=25K		

NH_3 (ammonia) was not considered as an option for the heat pumps as the technology was not developed at this point in time and will not be competitive in this size of application.

To choose the future systems a comparison was made between R600a and R744. Had warming of the water to higher temperatures been a requirement the R744 would have come out as the best candidate but for this application and site the R600a looked more promising for the heat pumps.

	KW
Cooling chillers	2250
Cooling HP as chiller	150
Cooling from HP	150
Freecooler	300
Heating capacity	450

For the chillers the preferred solution was R290. The 9 chillers each have a cooling capacity of 250 kW at 9˚C/15˚C using 27˚C as ambient design temperature. The cooling media circulated to the hospital is 35% propylene glycol and this is to cover the needs for the existing build area that covers 160.000m^2. The future extension will cover another 190.000m^2.

The replaced R22 chillers were reaching the end of their service life and the experienced leak rates were making an exchange necessary because it was becoming more difficult to keep getting recycled R22 in a market where most of the recycled material was imported from other countries where the R22 era was coming to an end when it comes to virgin R22.

The required hot water supplies are 70˚C in the summer period and 80˚C in the winter period. It is important to note that there is always a cooling need also in the winter months, to some extent generated by locally installed refrigeration systems.

RESULTS

The system is running perfectly well after some surprises on the regulation side. There are some conditions that have to be thought through. One of the essential questions was: is a heat pump primarily a refrigeration unit or is it a heat pump? The lesson learned is that it is essential to know if the heating load exists at the same time as the cooling load.

At the end of the project the customer was very happy with the new system and is pretty impressed with what has been achieved within the project, which also has a value in it self.

Johnson Controls

AQUAECO$_2$ BY SANDEN: THE FIRST CO$_2$ WATER HEATER TAILORED TO EUROPEAN NEEDS

SANDEN
Delivering Excellence

ABOUT THE COMPANY

The SANDEN Corporation, born in 1943, currently located in 23 countries, develops and produces full automotive AC loops, refrigeration retail systems, vending machines and thermal comfort appliances for buildings. This full products range is recognized worldwide for its high quality and reliability, as well as related services. Aquaeco2 is developed and produced by SANDEN Manufacturing Europe in France.

More information at:
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INTRODUCTION

Reducing CO_2 emissions is a clear leitmotiv for anyone concerned about the planet. Concrete targets have now been adopted by the European Union to promote green technologies and reduce energy consumption through the famous "3 x 20". Against this backdrop, SANDEN has decided to use core know-how in heating and cooling technologies: in order to reach the target for primary energy consumption in single family dwellings of ~50 kWhpe/m^2 year, investigating the development of better Domestic Hot Water (DHW) systems.

ABOUT THE SYSTEM

SANDEN has been providing so called "Eco Cute" solutions to the Japanese market for several years. However, importing this technology adapted to the specific needs of Nippon end users does not conform to its philosophy: the technology has to fit to the market, not other way round. This is the reason why a complete survey of the market needs has been conducted in order to define the design criteria that would lead to the best performances before starting any development.

The conclusion of this study was that CO_2 is the best possible refrigerant for reaching top level seasonal performances (seasonal coefficient of performance "sCOP" or seasonal performance factor "SPF"). This is due to a 100% thermodynamic mode over the full range of temperature, without any electrical back-up, and to CO_2 thermophysical and transport properties. By combining those performances with its truly green identity, CO_2 is clearly overtaking classically utilized HFC refrigerants, such as R134a.

In order to confirm *in situ* those specifications, SANDEN decided to conduct a field testing campaign of 10 products in one of the coldest area in France. A two and a half year development was necessary to reach the final product design, fulfilling all requirements for end users as well as giving to the European market a solution for producing really "green" domestic hot water.

RESULTS

Observations of the field testing campaign:

Real on-site performances and comfort levels have been achieved, ensuring the satisfaction of 10 families for almost 3 years now. In addition, 2 last generation prototypes were installed one year later in order to validate our mass production design: those have been running for almost 2 years.

SANDEN observed an SPF level reaching the initial target of 3, meaning that the DHW heat pump clearly takes advantages of the properties of CO_2, allowing to heat up water over the year without any electrical back-up.

A key figure of this field testing campaign is the system performance under extreme conditions (outside the theoretical temperature range) of outside air temperature of -19°C: COP level was still at 1.6, which is twice as good as any electrical resistance boiler. It illustrates why CO_2 allows a much better SPF compared to any other thermodynamic boilers using HFC, which cannot operate without electrical back-up under negative temperatures.

End users satisfaction:

Comfort is a key indicator for rating a DHW system: the advantage for a DHW heat pump is that it can heat up extremely quickly. Starting from a fully cold water tank, 20 minutes are enough to take a shower and 2 hours to entirely heat up the stored water. This feature allows a reduction in the volume of the tank to 150 litres at 65°C, which means improving the SPF by decreasing the static losses.

As a consequence of its high heating capacity, $Aquaeco_2$ is able to provide sufficient hot water to different family sizes (2 to 12 people).

Really green system:

$Aquaeco_2$ combines very low energy consumption through high performances with a truly green refrigerant. Without considering the advantages of the performance, the refrigerant choice by itself represents huge savings in terms of CO_2 emissions.

Installation and maintenance easiness:

$Aquaeco_2$ has been designed for an extremely easy indoor installation, in order to ensure that its inherent performance level is not damaged by a non-optimized installation. In addition, the flexible product layout (vertical or horizontal) allows to adapt to almost any type of house.

Local production

Following a development jointly managed by both Japanese and French Engineering teams, the manufacturing is exclusively handled by the already existing SANDEN Manufacturing Europe plant in Tinténiac (Brittany, France).

Summary:

- Always available DHW
- Intelligently adapted to European needs
- Truly ecological system
  - high performance: top of the class SPF for low energy bills
  - natural, non flammable, non toxic refrigerant
  - life-cycle analysis : setting new references
- COP = 3.2 according to EN16147 standard conditions
- Very quiet (40dBA)
- Reliable: based on a technology (CO_2 inverter) used for several years in Japan and tested in the field in Europe
- Easy indoor installation (vertical or horizontal) and maintenance
- Made in France

SANDEN
Delivering Excellence

GEA ADD ON HEAT PUMP FOR DAIRY HEAT RECOVERY

ABOUT THE COMPANY

GEA Refrigeration Technologies is a leading global group in industrial refrigeration. GEA designs, engineers, installs, and maintains innovative key components and technological solutions.

More information at:
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INTRODUCTION

Robert Wiseman Dairies (RWD), the largest fresh milk supplier in the UK, uses significant amounts of cooling to maintain food freshness, together with heat, which is used for pasteurisation and cleaning in place (CIP). Climate and environmental protection are high priorities at RWD:

- By 2030, RWD plans to eliminate synthetic refrigerants from its plants and replace them with natural substances;
- By 2015 the company aims to reduce its gas consumption.

With these considerations in mind a design study was undertaken to incorporate an ammonia-based heat pump that would use waste heat from the refrigeration cycle to boost pasteurising temperatures and thereby remove the need for a natural gas boiler. Following the study, an innovative ammonia heat recovery unit was installed in partnership with GEA.

ABOUT THE SYSTEM

The project objective was replace 3 ageing R22 water cooled chillers with a capacity of 2,500 kW with a central ammonia based refrigeration plant. Although replacing the R22 chillers with an NH_3 solution would give significant performance increases, the increased capital cost resulted in a poor return on investment (ROI) of 11 years. To improve the ROI GEA proposed a comprehensive solution including refrigeration capacity and the recycling of process and exhaust heat.

In a typical dairy such as the RWD Manchester site, the milk is cooled down to 2°C when it arrives, then a boiler is used to generate steam, which is used to pasteurise the milk, and through refrigeration the heat is removed using an evaporative condenser, cooling the milk back down to 2°C. This process generated a lot of waste heat. To improve the process a heat pump was put forward as a solution for the dairy's heating requirements, providing 80°C water for the pasteurisation process to replace the steam.

The GEA solution consists of a three-stage cascade system:

- The first stage includes thee GEA Grasso V 1100 speed-controlled refrigeration units. These cool the glycol-water circulation system to T0 = -5°C, with a temperature of Tc = 16 to 35 °C achieved on the compressor side;
- The second stage features one GEA Grasso 810 compressor, which has a T0 of 16 to 35 °C, and raises the temperature to 43°C;
- The third stage features two GEA Grasso 65hp heat pumps that raise the temperature from 43°C to 80°C.

The heat pumps use not only the exhaust heat from the refrigeration units but also virtually all waste heat produced in the entire plant.

RESULTS

Following the feasibility study for the ammonia system proposed by GEA, which showed net saving in utilities and a return on capital expenditure of 1.5 years, Robert Wiseman Dairies decided to invest in the combined central ammonia refrigeration plant and heat pump.

The investment meant there was no need for a boiler, which displaced a significant amount of gas, which as projected improved the payback. The capacity of the ammonia units, which is about 1MW, suffices not only for the pasteurisation but can also serve for the clean-in-place units.

The end result for RWD has been:

- A saving in CO_2 per year 1,135,000kg
- A net reduction in electrical energy for refrigeration and heating of 20%
- A reduction in gas usage of 52% from 6,470 CU. FT to 3,200 CU. Ft (52%)
- A water reduction of 50%

CASE STUDY

AMMONIA INSTALLATIONS BY GEA GRENCO AT LARGEST DUTCH VEGETABLE AND FRUIT PROCESSOR

ABOUT THE COMPANY

GEA Refrigeration Technologies is a leading global group in industrial refrigeration. GEA designs, engineers, installs, and maintains innovative key components and technological solutions.

More information at:
www.geagroup.com

CONTACT INFORMATION

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INTRODUCTION

Dutch company Vezet is one of the companies helping to meet the demand for packaged fruits and vegetables. This family-owned business has grown as the range and type of produce it can process has increased. Today the company is the largest vegetable and fruit processor in the Netherlands and produces 220 million units annually, expected to reach 330 million units in 2015. Vezet supplies major retail chains and food service companies with a wide variety of high-quality fresh cut, ready-to-cook vegetables, ready-to-eat salads and fruit salads.

An essential part of the process is keeping the food at the right temperature to preserve freshness. This is where refrigeration and cooling comes in. But, like many companies, Vezet has the challenge of replacing its refrigeration to meet regulations to eliminate the use of ozone-depleting man-made refrigerants in favour of natural refrigerants such as ammonia. This replacement has to be done without interrupting production.

ABOUT THE SYSTEM

Currently GEA Grenco is assisting Vezet to produce a master plan to transfer all old HCFC/HFC installations to ammonia refrigeration installations. The first ammonia plant was installed in 2007 – separate from the main factory – from which a cold carrier is supplied to various storage rooms. The second phase, in 2010, was to connect the ammonia plant to the main factory. This involved partly demolishing a factory building without obstructing the flow of goods between the two factories.

GEA Grenco supplied and installed air handling units, air coolers, compressors, condensers and heat exchangers – all tailor-made to Vezet's requirements. The ammonia compressor room established in 2007 was erected in a temporary position and will be re-used in a later phase of the master plan on a different location on the premises.

This plant now includes the following:

- Two Grasso Duopack units of 800kW (-11°/+35°C) each, and a receiver with two shell & plate heat exchangers
- An evaporative condenser and two GEA Küba air-cooled condensers with SS tubes, which can be found in the hybrid condensing part of the plant;
- A secondary system with the food safe cold carrier Temper® set up in a separate cold system (-8°/-2,5°C) and a separate warm system (+24°/+30°C).

The warm system is used for defrosting the air coolers and heating of the air- handling units in the cleaning mode of the areas. This warm system is heated by means of heat recovery of the oil cooling system of the compressors and a desuperheater in the ammonia discharge line.

During the process of the erection of the plant the demand for more cooling grew. At the end of the second phase of the project in 2010 the installed cooling-capacity on air coolers, heat exchangers and air handling was increased to over 3MW while the installed refrigeration machinery was still the initial 1.600kW

RESULTS

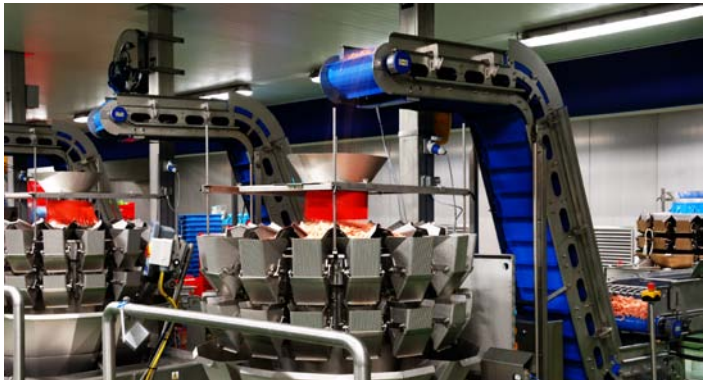
GEA Grenco has a long history in the design, erection, operation and maintenance of ammonia plants. Ammonia is considered to be a safe and very efficient refrigerant. Vezet is familiar with the ins and outs of ammonia and have operated a large icewater plant with ammonia since the mid 90's.

In the Netherlands refrigeration plants operated with natural refrigerants, such as NH_3, can be subject to tax deduction on the investment if certain design parameters are followed.

COP's are usually better with ammonia compared to most other refrigerants. In this particular case the efficiency of the whole of the plant should be taken in account. By means of a sophisticated control system with GEA Grenco software design, the use of proportional controls on valves, fans and pumps and an adaptive evaporation temperature control, it was possible to dose the cooling demand in such a manner that the plant was never operated at its limits so energy consumption is consequently low.

Vezet is very satisfied with the performance of the plant and the support of the GEA Grenco organization. GEA Grenco is now in a quotation process for the next steps in establishing the master plan.

In the phase coming up now a new refrigeration compressor room of ~ 4MW will be installed. A next step will be the phase out of the remaining HCFC/HFC installations and replace these with another NH_3-Temper plant.



CARRIER CORPORATION BUSINESS CASE FOR GREEN COMPETITIVENESS

ABOUT THE COMPANY

Carrier Corp., a unit of United Technologies Corp. (NYSE:UTX), is the world's leader in high technology heating, air-conditioning and refrigeration solutions. Carrier experts provide sustainable solutions, integrating energy efficient products, controls & services for residential, commercial, retail, transport and foodservice customers.

More information at:
www.carrier.com
www.carrier-refrigeration.com

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INTRODUCTION

In close cooperation with the largest food retail customers, Carrier Commercial Refrigeration has accrued sound CO_2 refrigeration technology experience with the launch of its innovative CO_2OLtec™ refrigeration system, which has more than 370 transcritical installations covering all retail store formats. Carrier's engineering team has accumulated an invaluable quantity of critical data positioning CO_2OLtec as the leading CO_2 transcritical refrigeration system based on energy efficiency, reliability and sustainability.

In Denmark and Switzerland the refrigerant CO_2 has become a technical standard for medium and low temperature refrigeration.

Carrier has the right refrigerant solution for every application, but not every application will use the same refrigerant.

ABOUT THE SYSTEM

CO_2OLtec provides both low temperature and medium temperature refrigeration solutions for all retail shop formats. The total impact of a refrigeration system in terms of greenhouse gas emissions, also called TEWI (Total Equivalent Warming Impact), is derived from the indirect emissions (energy consumption) and the direct emissions (refrigerant leakages) over the life-cycle of the refrigeration system.

RESULTS

Benefit for the environment as compared to the previous solution:
Low temperature compressors are connected directly to the suction side of the medium temperature compressors. This system configuration is referred to as a 'booster design.' The booster design, coupled with the advantages of not requiring oil separators and associated components, increases the efficiency of the CO_2OLtec system by an average of 10 percent versus a traditional HFC system or a CO_2 cascade system in mild to cold climate conditions. These efficiency gains are proven with measured energy consumption data in several system comparisons done by the food retail chains and by Carrier.

Attractive energy savings can be obtained with average annual temperatures of up to +15°C. This fact is in line with main results of the EPEE 'Eco-Efficiency Study of Supermarket Refrigeration'. For reference, the annual average temperature in: Stockholm, 7°C; Paris, 12°C; London, 11°C; Milan, 13°C; Madrid, 14°C.

Compared to a conventional HFC direct expansion refrigeration system, a CO_2 installation has no direct emission impact due to refrigerant leaks. A typical refrigerant leakage rate of 10 percent per year generates nearly half of the equivalent CO_2 emissions by a supermarket refrigerating system, if the refrigerant R404A is used. These direct emissions can be fully eliminated, if the natural and climate neutral refrigerant CO_2 is used.

For example, the potential reduction of greenhouse gas emissions for a hypermarket is equivalent to the CO_2 emissions of over 400 cars*.

Cumulated reduction of the CO_2 emissions by more than 370 stores equipped with CO_2OLtec:

- The reduction of CO_2 equivalent tons from 183.100 tons down to 93.400 tons result in a cumulated reduction of the CO_2 emissions by 89.700 tons which equals the take out of 27.600 average cars* from the streets by end of December 2011.

Financial benefits:
With CO_2OLtec refrigeration systems, storeowners select a reliable and environmentally responsible solution. CO_2 has the advantages of being a natural and cost-effective substance that enables storeowners to avoid refrigerant taxes and reduce their impact on the environment. The CO_2OLtec user can save energy, f-gas regulation related costs and refrigerant costs over the full lifetime of the system.

**Average car using 0.12 kg CO_2/km; run time 15,000 km per year*

Combining refrigeration and heating:
Carrier has developed a compact factory-built, standardized, add-on heating system, CO_2OLheat™, which includes heat exchanger, water pump, optimized CO_2 and hydraulic loop controls and full remote monitoring capability. Aligned in an optimum way to the CO_2OLtec refrigeration system, it is designed to utilize 100 percent of the available heat. Smart control algorithms provide the possibility to eliminate conventional heating sources almost entirely. High-energy efficiency, robust design, reliable operation and very attractive payback times make the new Carrier CO_2OLheat system the optimum addition to the existing product range.

In comparison to conventional refrigerants, CO_2 is the preferred solution for all aspects of supermarket refrigeration applications in mild to cold climate conditions in terms of:

- Sustainability
- Reliability
- Energy efficiency

Today, the industry is already working on a next generation of CO_2 systems for warm climates.

Keeping always in mind that the environment is precious.

CLOSING THE KNOWLEDGE GAP

ABOUT THE COMPANY

Alfa Laval has been a world-leading manufacturer of heat transfer, separation and fluid handling technologies, for more than 125 years. Today their products are used in a variety of industries including food and water supply, energy, environmental protection and pharmaceuticals.

More information at:
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INTRODUCTION

Green & Cool is the market's leading supplier of refrigeration systems that use environmentally-friendly carbon dioxide as a refrigerant. Based in Sweden, the company has grown rapidly since being established in 2007, and now distributes carbon dioxide refrigeration systems globally.

More information at: *www.greenandcool.com*

Green & Cool was founded in 2002 by two entrepreneurs in Sweden, who could see the huge market potential in carbon dioxide refrigeration. They weren't wrong, and in a few short years they've became the market's leading supplier, distributing CO_2 refrigeration systems across the globe. Alfal Laval, one of the world's leading manufacturers of air coolers and heat-exchangers, has also been quick to realise that the future of refrigeration lies in CO_2, so it is only natural that they've become a supplier to Green & Cool.

However the problem with being at the forefront is that you need everyone else to catch up, and today the market for CO_2 refrigeration is being held back by a shortage of expertise.

"We recognise that there is a lack of knowledge in the industry about this new refrigerant. It is one of the barriers holding back its spread," says Micael Antonsson, Technical Director and co-founder of Green & Cool. "We want to get everyone educated so that they feel secure in handling it. A lot of people think its rocket science but really it's the same technology as they come into contact with in their everyday jobs."

ABOUT THE ACADEMY

In response, the Green & Cool Academy has been created, which is essentially a training course in transcritical CO_2 technology for refrigeration technicians. Over two days, the course covers an extensive range of areas, from a general introduction to the technology to practical demonstrations of the equipment. It is offered in German, English, French, Dutch, Polish and all of the Nordic languages.

In recent years, Alfa Laval has also chosen to prioritise CO_2 technology and has become a leading manufacturer of CO_2 cooling systems. Currently they are the only manufacturer that can supply air coolers and plate heat exchangers for high-pressure units. Alfa Laval recently launched the Optigo range, a new series of commercial air coolers, designed for 80 bar pressure with small copper tube diameter optimised for CO_2.

Consequently, Alfa Laval also has a vested interest in expanding the knowledge of such technology within the industry, and so have leant their support to the Green & Cool Academy.

"This is clearly a growing market, particularly in Nordic markets and the UK," says Göran Hammarson, Key Account Manager, Alfa Laval. "But we can see that there is a lack of knowledge. Every time there is something new, there is resistance, and there are currently far fewer producers of machinery compared to traditional refrigeration equipment."

Alfa Laval's main contribution to the Green & Cool Academy has been to provide equipment and heat exchangers to their workshop. In addition, two Alfa Laval representatives, including Göran Hammarson, took part in the first training session.

"We want to continue to be one of the leading manufacturers in this segment. But we are also on a learning curve, we have to increase our internal knowledge too," says Göran. "Overall I thought it was very interesting. It was a good mix of technicians, consultants and sales representatives, combining both theory and practice."

Göran is not alone in responding so positively to the course and the first training sessions have proven to be a huge success, with participants giving the course an average score of eight out of ten. "People have already responded to the first training session, with requests for follow-ups," says Micael Antonsson. "It is clear that a lot of people want deeper knowledge and to be able to expand."

However with the rapid growth in CO_2 refrigeration set to continue, the need for better expertise will only increase. "The problem is that a lot of companies don't want to disclose they don't have the knowledge," adds Micael. "Those that don't adapt risk being left behind. Once you loose market share it is exceptionally hard to regain it." And if anyone still doubts that the future of refrigeration lies in CO_2, Micael is quick to point out that in many countries the trend is towards phasing out HFCs. "If you want to remain in this business in the future, you need to educate yourself now."

FIELD CASE STUDY OF INDUSTRIAL PLANT OPERATING WITH NATURAL REFRIGERANTS

ABOUT THE COMPANY

MAYEKAWA is a world-leading supplier of industrial cooling & freezing systems, refrigeration compressors, and heat pumps. It actively promotes the "Natural Five" refrigerants, among them ammonia, for air conditioning, freezing, and cold storage. Mayekawa/ MYCOM has more than 25,000 MYCOM compressors running in over 100 countries.

More information at:
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INTRODUCTION

In 2001 one of Cofely Refrigeration's customers decided to convert and increase the capacity and freezing temperature of a refrigeration plant from 1300kW at -42°C to 2900kW at -51°C. The refrigeration plant in question had been in use with refrigerant R22 since 1997.

For the installation it was suggested that the plant be re-built by re-using the installed compressors and using CO_2 to extend the plant capacity with lower process temperatures. The plant extension had to be executed between October 2004 and June 2005, starting with the conversion of the F250VLD units to N250VLD for use with NH_3.

The new plant was installed in 5 phases over the period staring from weeks 35 of 2004 to week 25 of 2005:

- 1: modification of R22 plant to NH_3 (from week 18 to week 23-2005)
- 2: installation of CO_2 equipment (from week 49-2004 to week 10-2005)
- 3: start-up of C5 & C6 (from week 10-2005 to week 14-2005)
- 4: start up of C7 (wk 16-2005)
- 5: start-up of C8 & C9 (week 18-2005 to week 20-2005)
- Full production from week 25-2005

ABOUT THE SYSTEM

The new plant for processing and freezing meat, would operate 24hrs/day 5 days a week, and would involve:

- Chilling in the process working rooms requiring -12°C;
- Product freezing with plate freezers (4x550kW);
- Quick freezing tunnel (1x600kW);
- Spiral freezer (1x600kW) requiring -51°C;
- Freezing in stores requiring -35°C.

In addition heat recovery would need to be incorporated to obtain hot water. The hot water would be used for:

- Process heating (55°C);
- Floor-/office-/load dock-/ expedition room heating (35°C);
- Bottom floor freezing room heating (12-14°C),

The requirement by the authorities was that the condensing temperature must not exceed 10°K above wet bulb-temperature

For low temperature side of the processing plant CO_2 applied in cascade with NH_3, used on the high temperature side, was selected. CO_2 was used for direct cooling of the freezers. NH_3 was used only for the high temperature side for cascade purposes, as the customer's environmental licence did not allow more than 2000kg NH_3 in the plant.

In addition the plant was equipped with following energy-saving options:

- - Heat recovery-high efficiency electrical motors;
- - Hot gas defrosting: for the freezers the CO_2 hot gas from the plant was used;
- - Frequency controllers;
- - Energy-saving condensers.

The freezing equipment operates following a load programme. In order to achieve the best COP per type of compressor 1 machine is equipped with a frequency convertor for speed control at part-load operation.

RESULTS

A comparison with synthetic refrigerant R507 was considered by Cofely Refrigeration, who concluded that this solution was much more expensive than the chosen CO_2/NH_3 concept. After project completion the customer reported that the CO_2/NH_3 plant is significantly more efficient than a comparable plant with R507.

In contrast to the original design of 32°C the average condensing temperature on the NH_3 cascade compressors was reduced to 25°C. This meant a power reduction of 151kWh or 906 MWh based on 6000hrs operation per year (COP-c increase of 8,7%). This represented an energy saving for the customer of €90,600 (based on €0,10/kWh). Heat recovery was 690 MW/year (for process use).

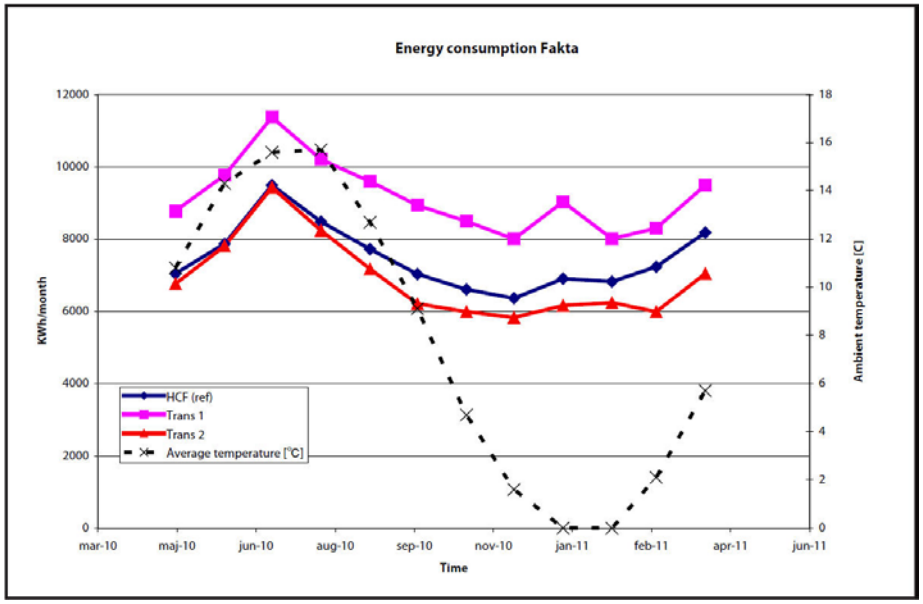
The calculated savings amount to 23% on energy, and a 49% saving on CO_2 equivalent emissions.

One of the project bottlenecks was the supply and availability of high-pressure components, as this plant was one of the first in Europe realised.

The customer is absolutely happy with the installation, which was built in full compliance with CE-PED.

With regard to future potential savings, as the process needs hot water at temperature levels of 70 to 80°C there is great interest to adding hot water overcompression heat pumps operating during the cheaper night-time power price, to buffer hot water for use during the production process. There is plenty of heat rejected from the high stage NH_3 cascade plant (over 4 MW per hour during production days), which can be used as heat source for the heat pumps. Therefore, for future plants where hot water is needed, the installation of hot water high-pressure compression heat pumps with NH_3 could help achieve significant energy savings by recuperating the condenser heat from the cascade NH_3 high stages, which is available in great quantities.

FIELD CASE STUDY OF SUPERMARKET PLANT OPERATING WITH NATURAL REFRIGERANTS



ABOUT THE COMPANY

The Danfoss group is one of the largest Danish companies, operating in: Refrigeration & Air Conditioning, Heating & Water and Motion Controls. Its Refrigeration and Air Conditioning division is specialised on automatic controls, compressors and electronic sensors.

More information at:
www.danfoss.com

CONTACT INFORMATION

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INTRODUCTION

The Danish Supermarket Chain, Fakta – owned by Coop Denmark has experienced significant energy savings with their second-generation transcritical booster system. By applying a CO_2 system Fakta has achieved 10% energy savings compared to HFC systems.

The Fakta chain has 378 stores in operation where 61 of them are transcritical. Fakta was one of the first movers to change to CO_2 and the first generation of transcritical systems were installed in 2007 (status end of 2010).

Fakta has continuously worked on lowering their energy consumption for the past 15 years, first on their HFC scroll packs and later on transcritical packs. As a result of this Fakta are now installing their second-generation transcritical packs where part load has been optimized.

ABOUT THE SYSTEM

Fakta and the remote monitoring centre AK Centralen have been collecting data from the systems for more than 15 years, since they first started optimizing the HFC pack with low energy consumption and temperature quality as main targets.

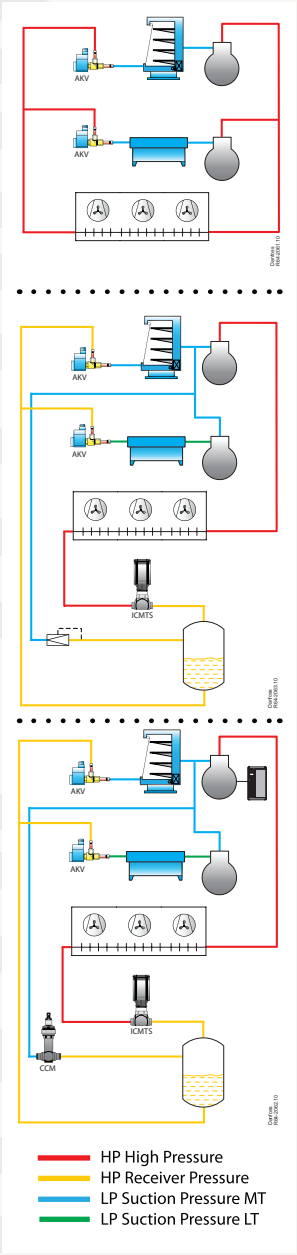
Whilst Fakta installations can be different, the cabinets, pack and gascooler always have the same arrangement. Today all systems are standardised and produced in batches of 5 packs with the same configuration regarding capacity, making Fakta a very good reference for energy studies.

For this case study an energy study 10 Fakta HFC systems, 10 Fakta- transcritical 1st generation systems, and 10 Fakta transcritical 2nd generation systems were analysed. The stores looked at are identical for most parameters, but the installations differ regarding length of pipes and number of bends. The maximum pressure drop in the pipe work is still the same for all systems regardless of refrigerant and installation.

For the installation to be included in the data material the following criteria had to be fulfilled:

- More than 4 months of operation since commissioning
- Equivalent size and opening hours

SYSTEM DESIGNS



HFC system:

- Parallel R404a system with very good load adaptation
- Controlled by ADAP-KOOL® pack controller and AKC 114A case controllers with electronic expansion valve type AKV
- 148 systems in operation
- 10 selected for the study

Transcritical 1st generation system:

- Booster system with gas bypass
- 2 compressors for MT (33/67%) and 2 for LT (33/67%
- Mechanical gas bypass valve
- Controlled by ADAP-KOOL® pack controller, EKC 326 controlling ICMTS high pressure valve, and AK-CC 750 case controllers with electronic expansion valve type AKV
- 32 systems in operation
- First 10 selected for the study.

Transcritical 2nd generation system:

- Booster system with gas bypass
- 2 compressors, one with AKD inverter for MT and 2 compressors without inverter for LT
- Controlled by ADAP-KOOL® pack controller, EKC 326A controlling ICMTS high pressure valve and CCM stepper gas by pass valve, and AK-CC 750 case controllers with electronic expansion valve type AKV
- 10 systems in operation May 2010 and 29 in December 2010
- First 10 selected for the study.

RESULTS

The energy data in this study was collected from May 2010 to April 2011. The plot, on the first page, shows energy consumption per month for the 3 different systems (HFC, Trans 1 and Trans 2) and the average ambient temperature for the month.

Application Engineer Kenneth B. Madsen from Danfoss explains "Our measurements indicate approximately 10% energy savings in Denmark when comparing the 2nd generation transcritical CO_2 system with the HFC system - with the lowest energy consumption in the cold months", and further "the results also show a technology improvement since 2007 where the first generation transcritical system was installed".

CONCLUSIONS

The results show that the 2nd generation transcritical systems in Fakta consume approximately 10% less energy than the HFC packs installed until 2007. Energy simulations indicate that the energy consumption in Denmark should be approx 10% lower than HFC systems, which are very much in line with the test results.

The difference in energy consumption between the 1st and 2nd generation CO_2 transcritical systems can be explained by: improved part load capabilities and smooth control of gas bypass as well as availability of components in smaller sizes to be able to better match the capacity for smaller systems; and a new CO_2 injection algorithm in AK-CC 750 and AK-CC 550a.

SINTEF ENERGY RESEARCH

ABOUT THE COMPANY

SINTEF - the Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology - is one of the largest independent research organisations in Europe. SINTEF Energy Research offers research and development services within refrigeration and power processes in general. Natural refrigerants and CO_2 in particular, has been a focus for the activity within refrigeration, mobile air conditioning, and heat pump systems.

The SINTEF research team working on refrigeration technology was instrumental in the "rediscovery" of CO_2 as a natural refrigerant in the late 80's.

CONTACT INFORMATION

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Petter.Neksa@sintef.no

3 KEY ACTIVITIES

HEAT PUMP PROCESSES AND SYSTEMS

SINTEF has more than 60 years of experience in research and development of heat pumping processes, systems and their components. Areas of expertise include:

- Heat pumping technology using natural working fluids
- Compact heat exchangers
- Compressors / expanders / ejectors
- SINTEF also maintains the Nordic region's largest laboratory of heat pump test rigs.

ENERGY EFFICIENCY IN INDUSTRY

SINTEF Energy Research has made a large and long-term strategic investment within energy efficiency in the industry. Through the KMB project CREATIV, a platform for research and development, SINTEF boosts the development and deployment of energy efficient technology in industry, in particular heat pumping technology based on natural working fluids. Work is divided into the following areas:

- Power processes for electricity generation from waste heat
- Utilization of thermal surplus energy
- Industrial ventilation
- Storage of thermal energy
- Efficient heating and cooling
- Thermal processing

The main goal of CREATIV is to demonstrate that more than 25% reduction in energy consumption and greenhouse gas emissions is possible by 2020 - through long-term joint R & D efforts in cooperation with the Norwegian and international industry and research institutes.

POWER GENERATION FROM WASTE HEAT

SINTEF works on the development of processes and systems for power generation from waste heat and offers professional support in:

- System analysis and estimation of the potential, using advanced tools
- Design of key components (heat exchangers, turbines and pumps)
- A wide network of technology providers
- Close dialogue with support agencies such as Enova and Innovation Norway
- Development of technology based on the transcritical cycle, using CO_2 as the working fluid

SINTEF

Using Earth's resources wisely

At SWEP, our constant innovation enables us to supply the latest environmentally friendly technology to the market.

Our dedicated range of BPHEs for climate-neutral refrigerants provides reliable performance across a wide range of applications.

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SWEP
A DOVER COMPANY

EUROPE TOMORROW

TRENDS, FORECASTS & EXPECTATIONS

EUROPEAN INDUSTRY VIEW ON AWARENESS LEVELS, PRODUCTS & PLANS

Close to 700 European industry experts have voiced their concern about low awareness levels among customers and the HVAC&R industry as a whole about CO_2, NH_3 and HCs as refrigerants – a major stumbling block to their rapid market adoption. Which products & services involving HFC-free solutions are used today, and which natural refrigerants will dominate in future innovations? The answers on ….

PAGE 87

A SWOT ANALYSIS FOR NATURAL REFRIGERANTS IN EUROPE

Natural refrigerants have their strengths and weaknesses, as does every refrigerant option. But besides substantially reducing direct emissions from high potential global warming gases, they can also save costs and "future-proof" the industry from upcoming legislation, says the industry. See how the current European policy & business climate impacts on natural working fluids, and why training & know-how remains a hurdle, on…

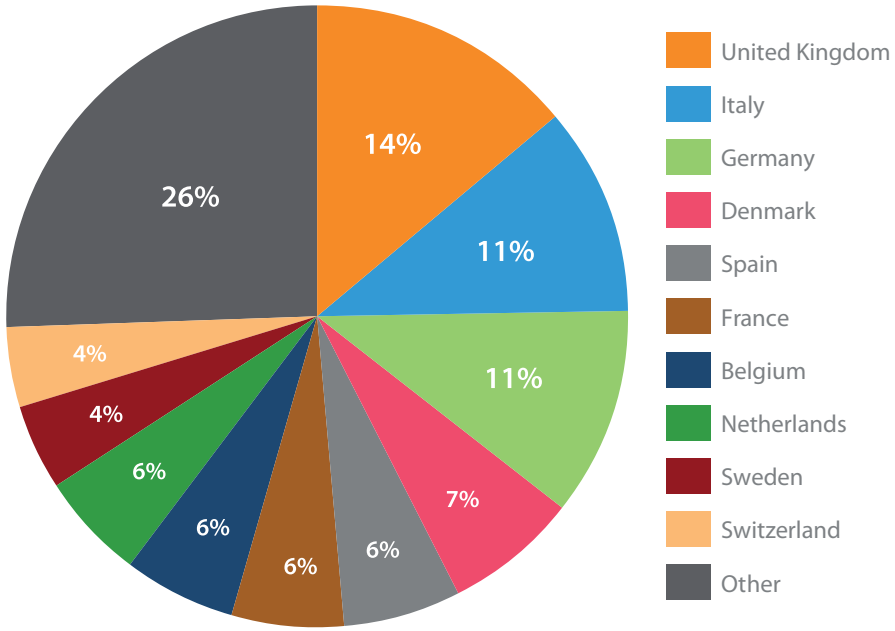
PAGE 102

THE FUTURE OF CO_2, NH_3 AND HCs – MARKET FORECASTS 2012-2020

Prospects for natural working fluids are heterogeneous, strongly depending on the HVAC&R sub-sector and its capacity to absorb technologies based on non-fluorinated gases. From promising figures for the commercial and industrial refrigeration sectors to a currently stagnating market for mobile air conditioning - see how Europe's natural refrigerant industry has looked into the future, on…

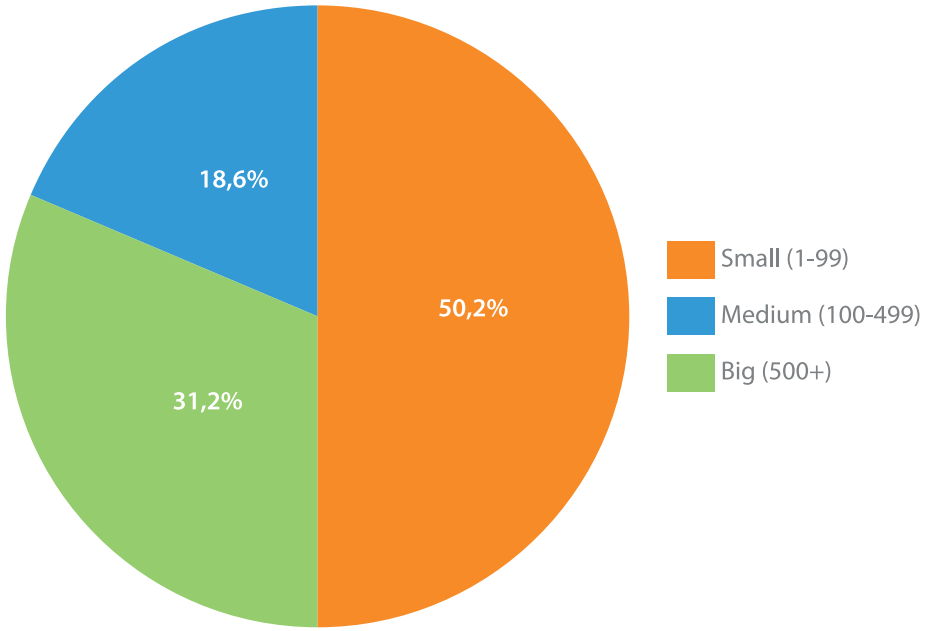
PAGE107

EUROPEAN INDUSTRY SURVEY – RESPONDENTS PROFILES



EUROPEAN COUNTRIES REPRESENTED

Most respondents to the industry survey came from the UK, followed by Italy, Germany and Denmark. This is unsurprising as development of natural refrigerants components and systems is strong in these countries, and hence interest in taking the survey on the market uptake of natural working fluids was pronounced. Overall, 666 respondents out of a total number of 1,254 were included in further analysis for the European market.



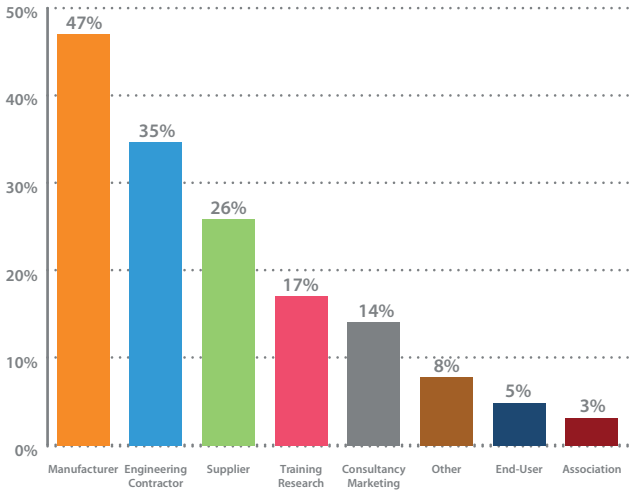
ORGANISATION SIZE

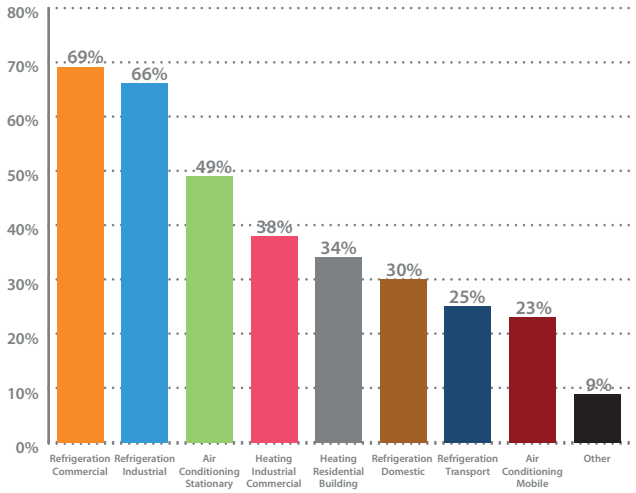
In terms of organisation size represented in the survey results, more than half of all respondents were active for a small organisation with less than 100 employees. Close to 19% came from a medium-sized enterprise, and 31% represented large organisations with more than 500 staff members.

TOTAL respondents: 666

EUROPEAN INDUSTRY SURVEY

RESPONDENTS PROFILES





ORGANISATION TYPES

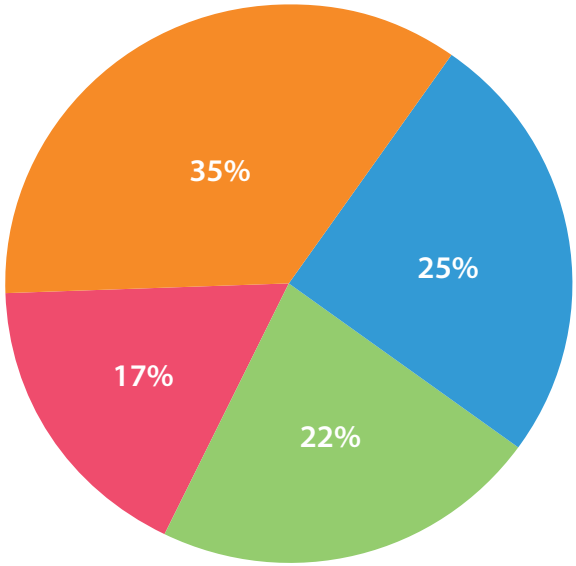
Nearly half of all respondents represented system manufacturers, followed by engineering & contracting services, and component suppliers. Training & research was the 4th strongest activity in the total response set. Answers allowed for multiple choices and indeed a high number of participants were active in several fields, especially in large organisations combining research, manufacturing and contracting. End-users and associations were represented by 8% of respondents.

TYPES OF ACTIVITIES (INDUSTRY SECTOR)

A large majority of respondents, 69% and 66%, are active on behalf of organisations involved in commercial refrigeration and industrial refrigeration – the two industry sectors with highest current and projected use of natural refrigerants in Europe. Less pronounced are activities in stationary air-conditioning, as well as industrial, commercial and residential heating. Not surprisingly, the mobile air-conditioning industry as one that is at present not a lead sector for CO_2 or HCs, is represented only to a minor extent.

NATURAL REFRIGERANT PRODUCTS TODAY & TOMORROW

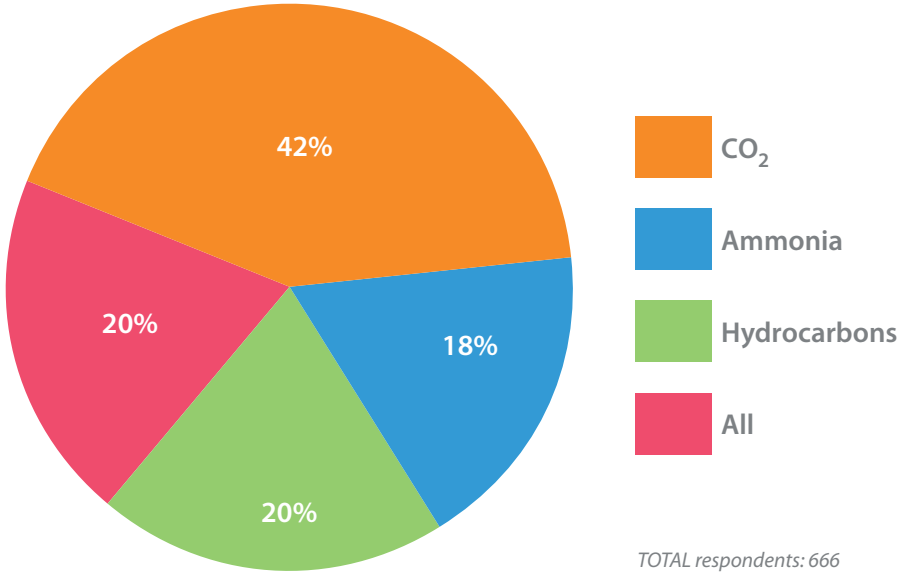
QUESTION: "Which Products & Services for Natural Refrigerants do you HAVE?"



CO_2 USED IN MOST PRODUCTS & SERVICES TODAY…

When looking at the natural refrigerant products and services offered by European corporations today, the high percentage of R744-related activities (35%) is noteworthy. Ammonia and hydrocarbons are nearly on par, whereas 17% of all respondents are active for organisations with products and services for all three natural refrigerants.

QUESTION: "Which Products & Services do you PLAN TO HAVE?"



TOTAL respondents: 666

… AND TOMORROW

When asked about the natural refrigerants products and services planned, the 67 responses included in the analysis confirmed the positive trend for carbon dioxide-based systems. 7% more respondents see their product portfolio include CO_2-related activities, whereas the prospects for ammonia (-7%) and hydrocarbons (-2%) are less positive. However, participants estimated that activities involving all three natural working fluids will increase by 3% in the future.

EUROPEAN INDUSTRY SURVEY

As a sub-set from the global industry survey (see page 28), and to find out where the European NR industry might be heading over the coming years, only respondents active for organisations located in Europe were selected for further analysis. Hence, out of the initial 1,338 individuals completing the survey, 666 were heard on items as varied as information sources for natural refrigerants, the use of NR products & services today and in the foreseeable future, or the overall policy & business climate for NR. Participants also analysed barriers and strengths of natural working fluids, and attempted an outlook into the period until 2020 to evaluate the market presence NR would have per industry sector.

STRONGEST INTEREST IN THE UK, ITALY, GERMANY & DENMARK

Most respondents taking the survey are located in the UK (14%), followed by Italy and Germany (11%), and Denmark (7%). This is not a surprising result as especially in those countries many leading system and component suppliers for NR technology are to be found that are active across Europe and beyond. Despite its small overall industry size, the Danish HVAC&R industry was strongly represented – a result of its wide use of HFC-free technologies and developed expertise on NR. By geographic region, Western Europe is represented with 49%, Southern Europe with 26%, Northern Europe with 17% and Eastern Europe with 8%.

Most respondents (50%) represented a small organisation with less than 100 employees. Close to 19% came from a medium-sized enterprise, and 31% represented large organisations with more than 500 staff members.

MANUFACTURERS & SUPPLIERS LEADING RESPONSE GROUP

As regards the main types of activities, 47% of respondents represented a system manufacturer, followed by engineering & contractor, component suppliers and training & research providers. As multiple choice was allowed, it can be concluded that a high number of organisations are active in several fields. Crosstabs applied to the total response set regarding the organisation's size indicated that mostly very big or very small companies were represented in the manufacturing business, whereas component supply was mostly done by small businesses. The engineering / contractors business is strongly dominated by small companies (149 responses for "small" versus 42 for "medium" and 39 for "large"), as well as the consultancy / marketing business.

COMMERCIAL & INDUSTRIAL REFRIGERATION

A large majority of 69% and 66% are active for companies involved in commercial refrigeration and industrial refrigeration. This is unsurprising as these two industry sectors are currently among the most promising ones for the use of natural refrigerants until 2020, as industry's forecasts have shown (see page 104). The Mobile Air Conditioning, Transport Refrigeration and Domestic Refrigeration sectors are only represented to a significantly lower extent. This can be explained by the unfavourable climates for NR use in the first two cases, and the lack of interest in taking the survey following the established market situation for HC refrigerators across Europe in the latter case.

Again, the commercial refrigeration sector is mostly represented by small companies (223 responses) as compared to large companies (149 responses). The same distribution pattern is applicable for the industrial refrigeration sector.

THE FUTURE OF NR PRODUCTS

An overwhelming majority of those taking the survey (75%) already had NR products and services in their portfolio, hence expressing their strong interest in more consolidated data in this specific area. Among those offering NR solutions, most offered CO_2-based products and/or services. However, it has to be noted that distribution is relatively balanced between the three refrigerant options. 17% showed clear leadership by offering technology for all three refrigerants CO_2, ammonia and hydrocarbons. As regards the organisation size, small businesses are represented to a higher-than-average extent in the NR industry taking the survey, followed by large companies with more than 500 staff members.

In the future CO_2 will increase in importance for the respective organisations, with 42% stating that future products and services would involve R744-based solutions. The percentage of businesses offering technology for all three refrigerants is also expected to increase.

ATMO sphere AMERICA the Business Case natural refrigerants

June 12-13 2012 | Washington DC

THE BUSINESS CASE FOR NATURAL REFRIGERANTS IN NORTH AMERICA:

The first-ever North American ATMOsphere Natural Refrigerants Workshop will be held in Washington, DC on June 12-13, 2012.

ATMOsphere America 2012 comes at a time when more and more companies in the US and Canada are looking into Natural Refrigerants as alternative working fluids in commercial and industrial refrigeration, heat pumps as well as air-conditioning applications.

Around 200 key industry experts and stakeholders are expected to attend ATMOsphere America 2012 to discuss the Business Case for Natural Refrigerants. This dynamic, interactive event will engage participants, enhancing awareness and exploring the promising potential of the use of natural refrigerants such as CO_2, ammonia and hydrocarbons in the North American market.

June 12 - 13, 2012
The Liaison Capitol Hill Hotel, 415 New Jersey Avenue NW
Washington DC, USA
www.ATMO.org/America2012

www.ATMO.org

Upcoming ATMOsphere events

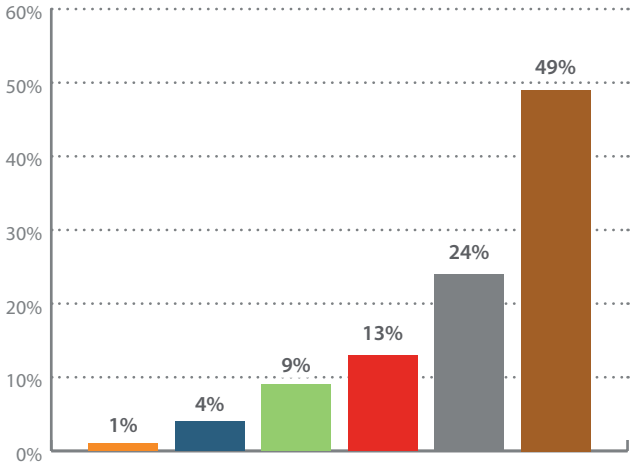
4th Edition of ATMOsphere Europe
Brussels, September 2012

1st ATMOsphere Asia, early 2013

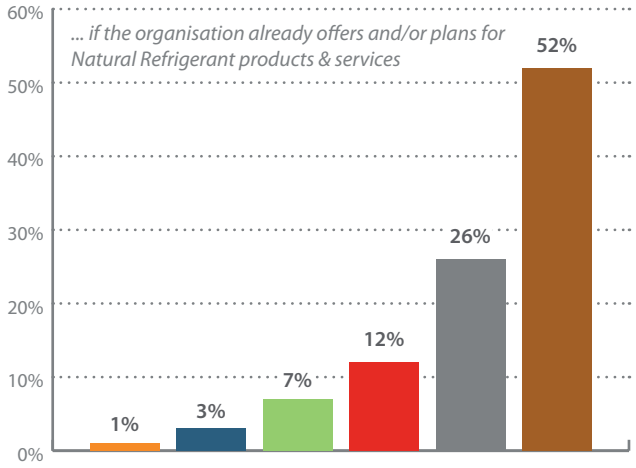
INFORMATION AND AWARENESS LEVEL

RESPONDENTS

QUESTION: "How informed are you about Natural Refrigerants?"



There is a high overall level of awareness about natural refrigerants' characteristics and usage among respondents to the European industry survey - 73% of all respondents are either "highly informed" or "well informed". Awareness levels rise even higher when only those respondents offering natural refrigerant solutions and/or planning to offer them in the near future are selected.



In this sub-set, only 11% are not well informed about natural working fluids (awareness level up to 40% out of a maximum of 100%), and a clear absolute majority (52%) has an excellent awareness level. Results imply that natural refrigerants are well known about among manufacturers, engineering contractors and suppliers taking an interest in the future of CO_2, NH_3 and HCs.

Scale: Level of Awareness

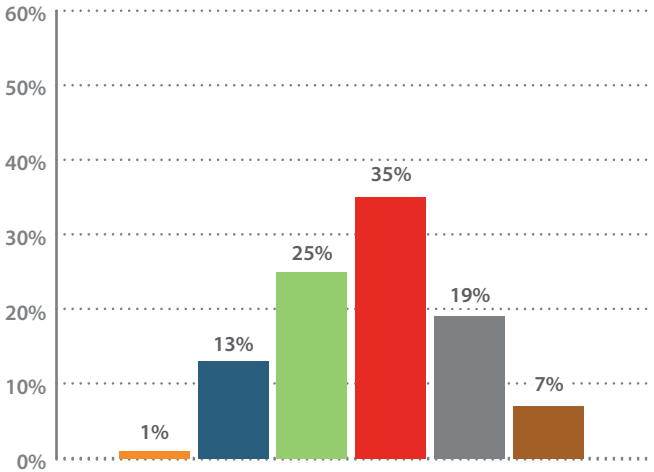
- 0% (not informed)
- 1 - 20% (poorly informed)
- 21 - 40% (rather poorly informed)
- 41 - 60% (rather well informed)
- 61 - 80% (well informed)
- 81 - 100% (highly informed)

TOTAL responses: 657

INFORMATION AND AWARENESS LEVEL

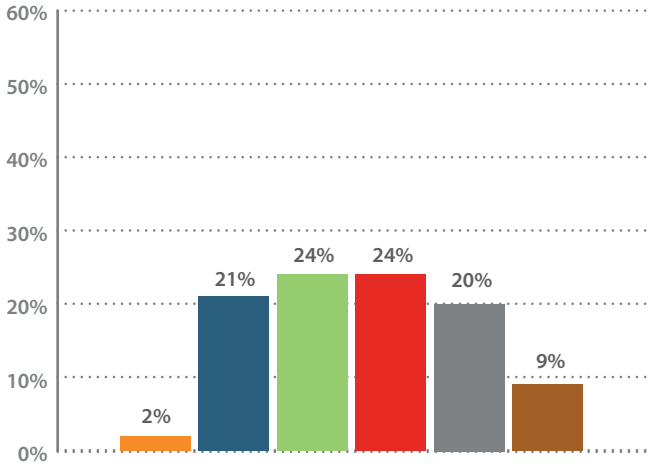
HVAC&R INDUSTRY & CUSTOMERS

QUESTION: "How informed is the HVAC&R industry about Natural Refrigerants?"



The results about the level of information in the HVAC&R industry as a whole are markedly different from awareness levels among respondents. More than a third of respondents (39%) believe that the industry as such is "not informed" to "rather poorly informed". Only 7% of respondents think the industry is "highly informed" about the characteristics of natural working fluids.

QUESTION: "How informed are your customer about Natural Refrigerants ?"



Results about the level of information of respondent customers follow a similar pattern, with almost 70% of respondents believing that customers are at best "rather well informed" - including all awareness levels of up to 60%. Contrary to the high level of information among respondents, these results suggest that whilst manufacturers and system suppliers are well aware of natural refrigerants, end-users lack information about natural refrigerants.

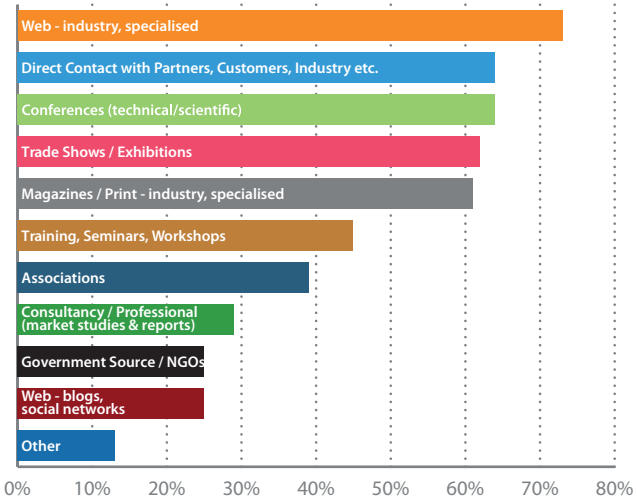
Scale: Level of Awareness

- 0% (not informed)
- 1 - 20% (poorly informed)
- 21 - 40% (rather poorly informed)
- 41 - 60% (rather well informed)
- 61 - 80% (well informed)
- 81 - 100% (highly informed)

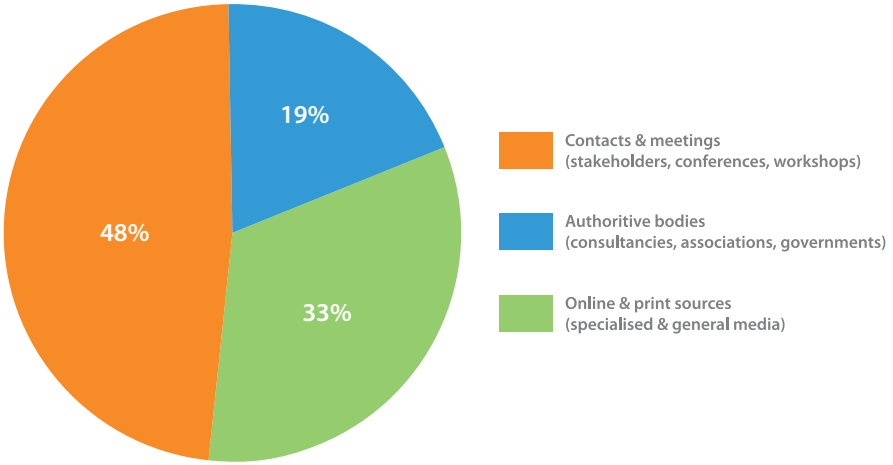
TOTAL responses: 657

INFORMATION SOURCES

QUESTION: "Which sources do you use to get information about Natural Refrigerants?"



... information sources grouped by type



TOTAL responses: 3260

SPECIALISED WEBSITES, DIRECT CONTACTS & INDUSTRY EVENTS ARE KEY FOR STAYING INFORMED

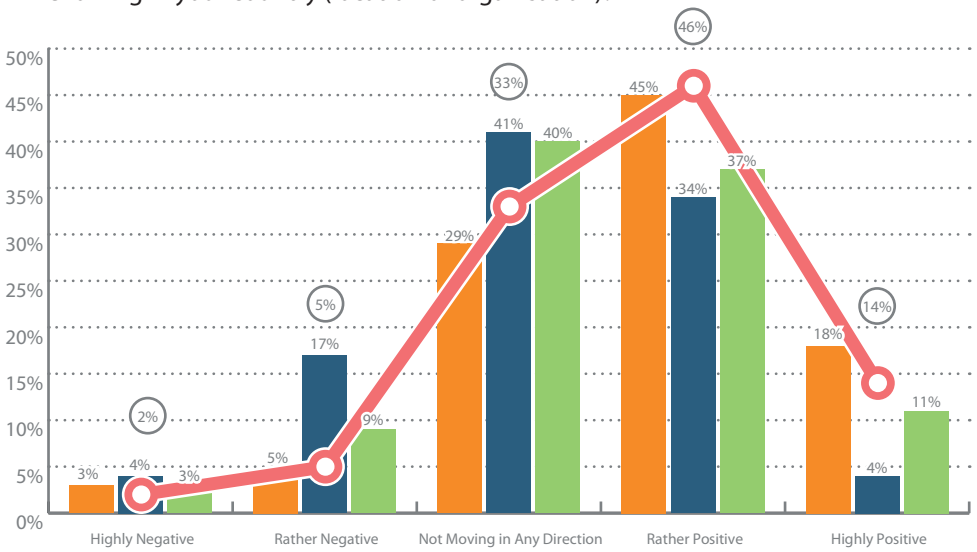
From 3,260 total responses received (multiple choices possible), a clear majority of participants (73%) is staying informed on the market situation for natural refrigerants through specialised websites. Information sources of similar high value include direct contacts with partners and customers (64%), technical and scientific conferences (64%), trade shows (62%) and print magazines (61%). Online blogs and other social media channels, as well as government / NGO sources are used to only a minor extent.

MEETINGS REMAIN MOST POPULAR INFORMATION SOURCE

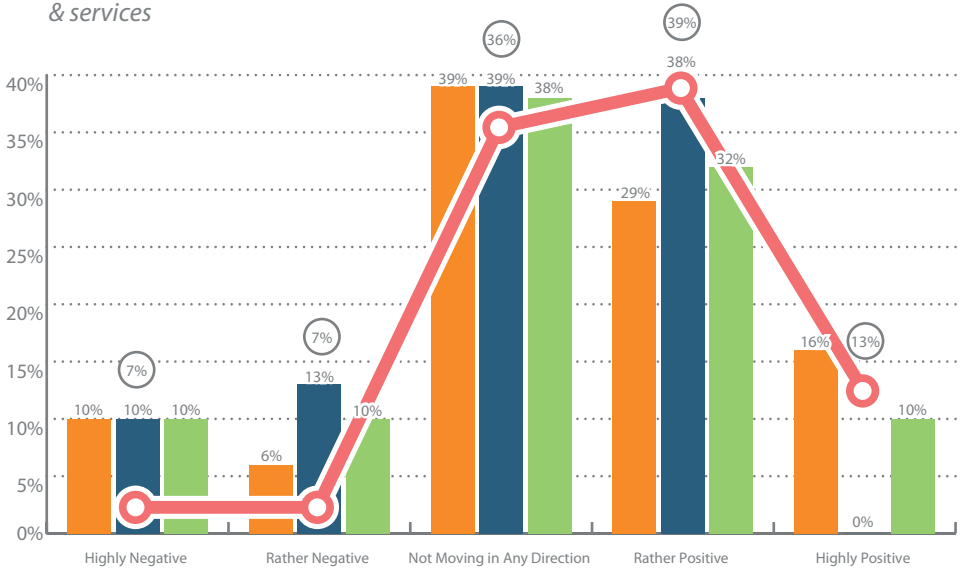
If all individual response options are grouped by the overall type of information provider and channel used, face-to-face meetings during individual talks, conferences, workshops and trade shows emerge as the most popular source of information on natural refrigerants. This is then followed by online & print sources (specialised and general media) used by 33%, and authoritive bodies (associations, consultancies, governments / NGOs) serving for 19% of all respondents as an information source.

BUSINESS & POLICY CLIMATE

QUESTION: "How is the Business and Policy Climate evolving in your country (location of organisation)?"



... if the organisation does not offer or have plans to offer Natural Refrigerant products & services



46% SEE RATHER POSITIVE CONDITIONS FOR NATURAL REFRIGERANTS

Overall, the market & policy conditions for natural refrigerants are rated as being rather positive ones. However, when looking at the conditions per natural refrigerant, marked differences can be found: while CO_2 can count on the best perceived frameworks for market expansion, hydrocarbons seem to face the highest challenges at the moment. This, however, can partly be attributed to the fact that a majority of respondents come from Europe where the market prospects for CO_2 are generally positive.

Ammonia
Hydrocarbons
CO_2
NR overall

NON-NR REFRIGERANT INDUSTRY MORE SCEPTIC

Only taking into account respondents not offering or planning to offer natural refrigerant services or products, the business & policy climate for natural working fluids overall is also considered to be a rather positive one. Divided by refrigerants, however, respondents are generally more sceptic than their NR counterparts, with 10% saying that conditions for ammonia, carbon dioxide and hydrocarbons individually are highly negative, and around one-third saying that the markets and policy frameworks would not be moving in any direction.

Ammonia
Hydrocarbons
CO_2
NR overall

TOTAL responses: 511

BUSINESS & POLICY CLIMATE FOR NATURAL REFRIGERANTS

The speed and level at which natural refrigerant systems become an established solution on the European market depend on policy and industry conditions likewise. 511 European respondents were asked to answer the question "How is the Business & Policy Climate evolving in your country?" for Natural Refrigerants overall, and for each of the three refrigerants surveyed: ammonia, carbon dioxide and hydrocarbons. The results obtained paint a clear picture of how different the situation is evaluated for each specific refrigerant, where CO_2 seems to face the brightest future, whereas hydrocarbons are confronted with greater challenges (outside domestic refrigeration).

NATURAL REFRIGERANTS OVERALL

When asked to evaluate the business and policy climate for natural refrigerants overall, respondents tended to rate the current situation in Europe as "rather positive". The highest absolute agreement rate (46%) was hence registered for this option. Only 7% were pessimistic ("highly negative" and "rather negative"), while a total of 60% were optimistic ("rather positive" and "very positive"). One-third was undecided if current market and industry trends would favour or block the usage of CO_2, NH_3 and HCs. Interestingly, the ratings for "NR overall" were on average more positive than the individual ratings for "ammonia", "CO_2" and "Hydrocarbons" would have suggested. In fact, responses for the "NR overall" situation were closest aligned to the values for "CO_2" for all categories. This might be related to the fact that most respondents to the survey represented the commercial and industrial refrigeration industry where CO_2 is a promising candidate, and hence the evaluation for the natural refrigerant industry as a whole was influenced by the respondent's positive experience in these two sectors. Overall, responses obtained are also closely related to the industry expectations per sector and the barriers to the uptake of natural working fluids (see pages 98 to 99 & pages 104 to 106).

Unsurprisingly, the sub-set of respondents not planning to use natural refrigerants rated the situation for "NR overall" slightly more negatively. 14% (versus 7% for all respondents) evaluated the current situation as being negative, and 36% (versus 33%) did not see the business and policy climate moving into any clear direction. However, interestingly, also here a clear majority of 52% (versus 60% for all respondents) were optimistic about the overall policy and business frameworks in place today for NR.

CO_2: BLUE SKIES AHEAD?

When looking at the ratings for CO_2 individually, respondents are generally largely optimistic about the evolving industry and policy climate. Only 8% of participants believed the current situation in their European country would be "highly negative" or "rather negative", whereas 63% rated conditions to be "rather positive" or even "highly positive". This result is well above the average given for ammonia and hydrocarbons, and tends to reflect positive outlooks for carbon dioxide in several applications, including (light-)commercial and industrial refrigeration. However, caution should be applied as close to one-third (29%) were uncertain about the direction the market would take.

Participants with no plans to use R744 were significantly more pessimistic about supporting market and policy frameworks put into place in Europe today. 10% rated the situation as "highly negative" for CO_2, balanced by 16% on the other end of the spectrum stating it would be "highly positive". In between, most of all respondents were unsure about the direction markets would take in the current climate. A marked difference can hence be seen between organisations already investing into CO_2

and those with no intention to do so in the foreseeable future – the latter especially showing a clear tendency towards the "no movement" option as compared to the "rather positive" one.

NH_3: STABLE CLIMATE WITH SUNNY PROSPECTS

The first noticeable result, when comparing the total response set and the sub-set including only organisations with no plans to use NR in the near future, is that there are no marked differences between them. While more individuals said the situation for ammonia in Europe would be "highly negative" (10% for "No NR" subset as compared to 3% for all respondents), evaluations for all other options followed similar patterns. Average responses tend towards the "no movement" to "rather positive" option, irrespective of whether the company uses natural refrigerants or not. This is another indication of the largely saturated and well-established NH_3 market for some applications, mainly industrial systems, already pointed out for the refrigerant sales trends (see pages 32 to 33) .

HC: CLOUDY FORECAST

Overall, HC represents the market with the least favourable policy and business climate in Europe, as compared to CO_2 and NH_3. One-fifth (21%) rate the current situation as "highly negative" or "rather negative", as compared to only 8% for CO_2 and 12% for NH_3. At the other opposite, only 4% say HCs meet "highly positive" conditions. Even the total of those seeing any positive movements ("rather positive" and "highly positive") amounts to 38% only, as compared with 63% for CO_2 and 48% for NH_3. For those not (yet) involved in HC products & services, no single respondent selected the "highly positive" option.

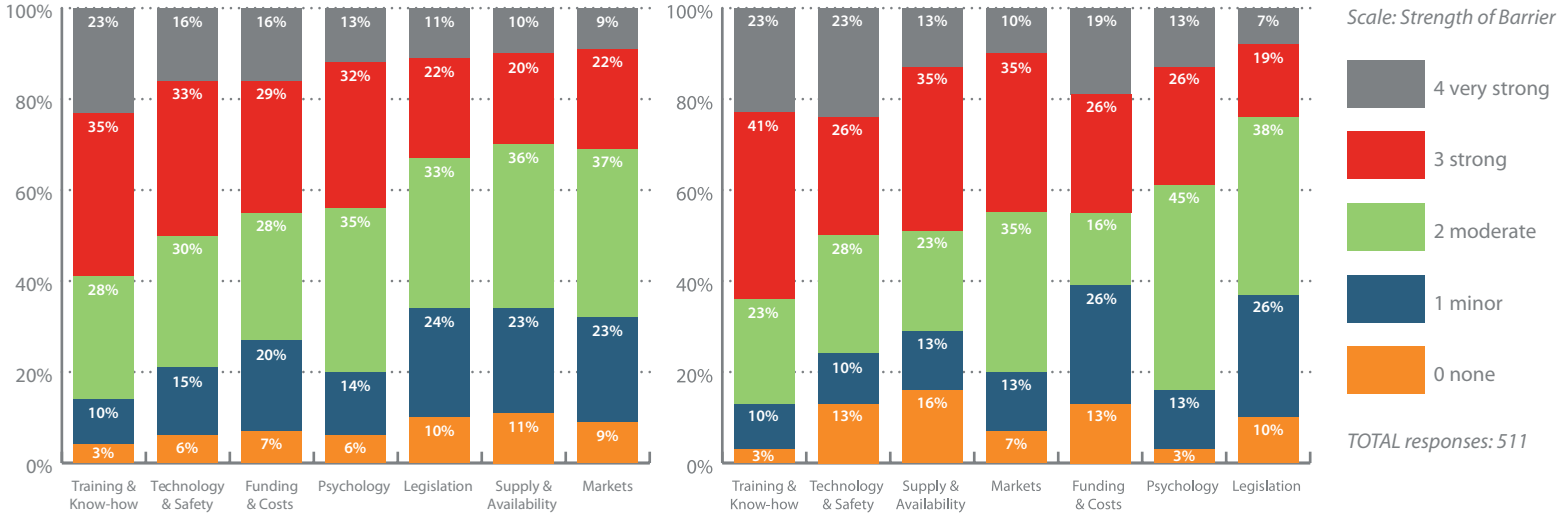
A possible explanation for this rather pessimistic evaluation can be found in the low total response rate of the domestic refrigeration industry - a traditional stronghold of HC application in Europe. Outside this industry the usage of propane, isobutane and other HC refrigerants is strongly restricted by European and national charge limits impeding the widespread use of HCs in larger installations. Results for HCs can therefore be interpreted as a valid reflection of some of the prevailing barriers to the uptake of natural refrigerants: training, safety and legislation (see pages 98 to 99 & 102 to 103).

BARRIERS TO THE UPTAKE OF NATURAL REFRIGERANTS IN EUROPE

TRAINING, TECHNOLOGY DEVELOPMENT & COSTS REMAIN THE MAIN CHALLENGES

QUESTION: "What are the biggest barriers in adopting Natural Refrigerants?"

... if the organisation does not offer or have plans to offer Natural Refrigerant products & services

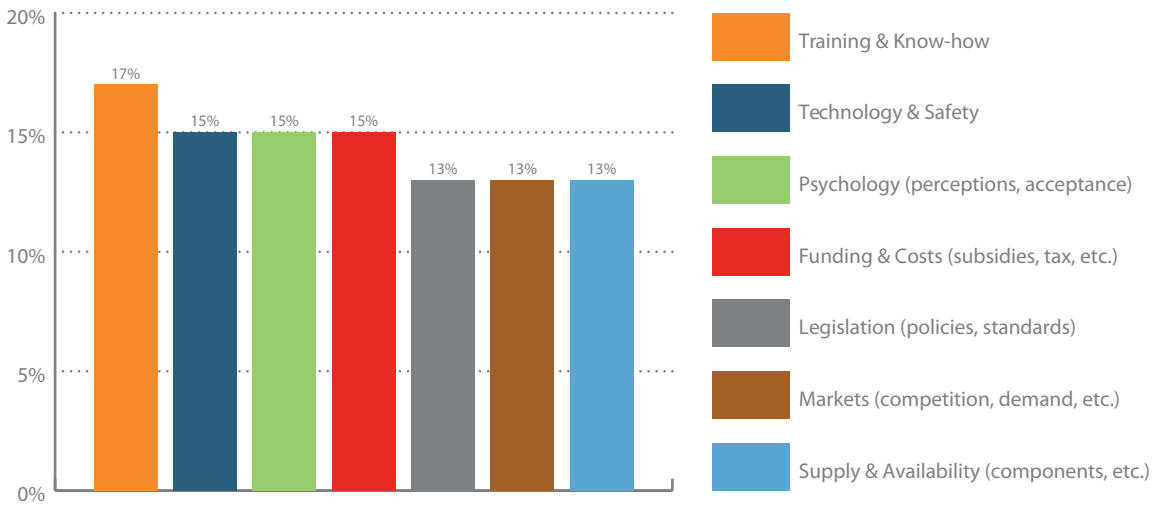


Lack of training and know-how is a "strong" to "very strong" barrier impeding the wider uptake of natural refrigerants, a clear majority of 58% finds. This is followed by technology & safety aspects, and cost issues – mainly due to higher capital costs for natural refrigerant systems and a lack of economies of scale for some applications. Of less importance are unfavourable competition issues, lack of demand or unavailability of systems in Europe to the 511 respondents.

Similarly, the sub-set of respondents with no intention to use natural refrigerants confirms training & know-how and a need for technology development as the two strongest barriers (strong / very strong). However, they contradict the appreciation that "psychology" – lack of awareness and misconceptions – would constitute a major barrier, but put a lack of supply and current market conditions (demand / competition) much higher up in the list of prevailing challenges.

LACK OF AWARENESS THE 3RD STRONGEST BARRIER

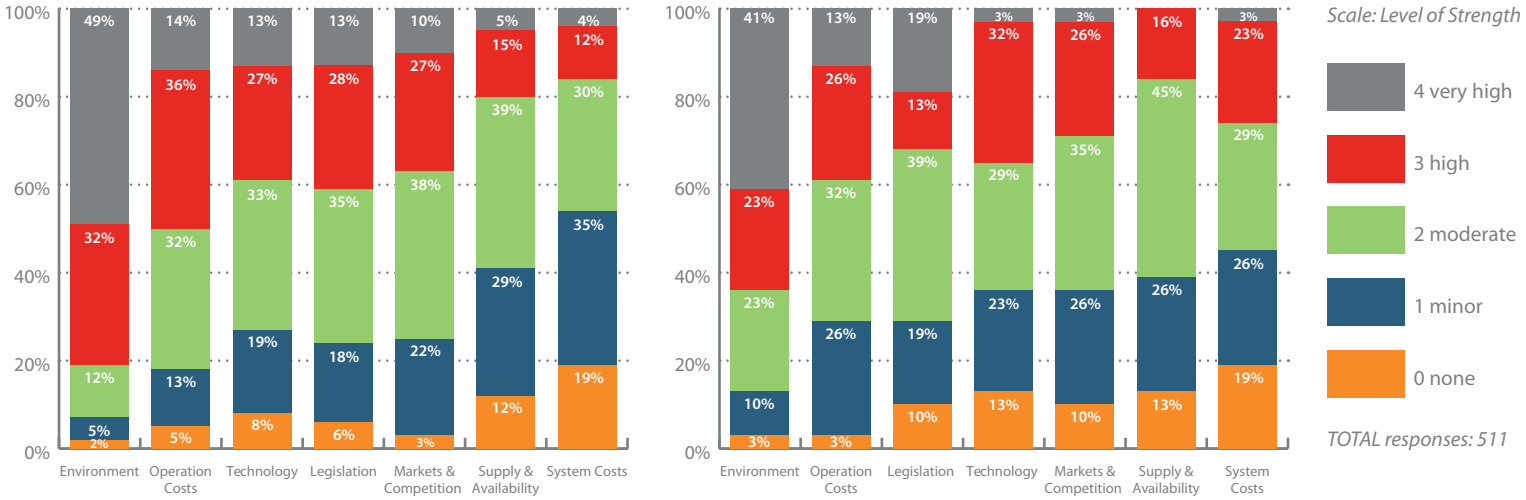
QUESTION: "What are the biggest barriers in adopting Natural Refrigerants?" - average values



When all barriers are weighted according to their strength, the psychological factor moves up to become the third-largest overall challenge. This result ties in well with the lack of awareness stated for the HVAC&R industry as a whole and specifically for customers (see pages 92 to 93) Still, need for more training remains the biggest barrier, followed by required investment in technology development, including safety.

... AND THEIR STRENGTHS

QUESTION: "What are the biggest strengths of Natural Refrigerant applications?"



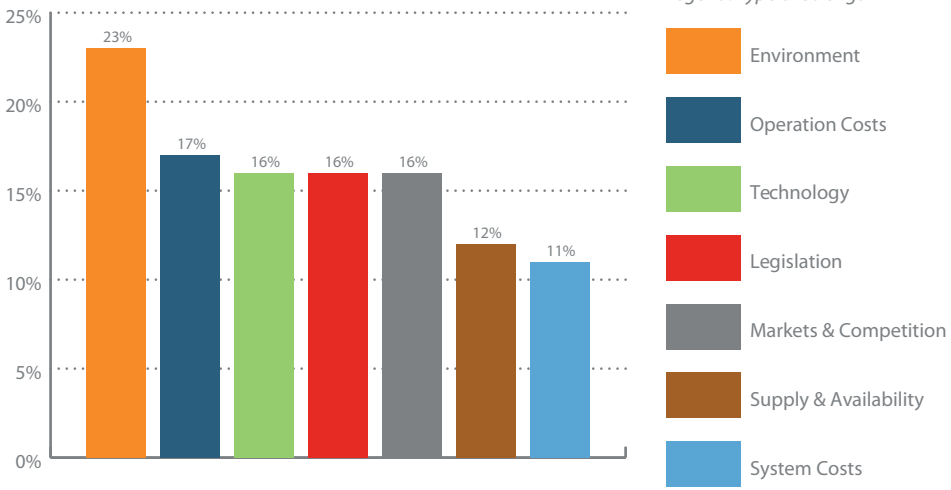
ENVIRONMENT, ENERGY SAVINGS & LIFE-CYCLE COSTS KEY ADVANTAGES OF NATURAL REFRIGERANTS

With 81% of all respondents saying environmental benefits constitute a high or very high strength of natural refrigerants, direct and indirect emissions reductions, including energy savings are the most important reasons to opt for HFC-free solutions. This is then followed by operation cost savings confirmed by half of all respondents (50%) as being a strong/very strong benefit, and technology – including reliability, durability, weight and efficiency.

For the sub-set of respondents not planning to have natural refrigerant products, the environmental aspect still dominates with 64% saying this is a high or very high benefit. Unsurprisingly, this group consistently sees more "none" to "minor strength" in all fields, except for system costs which they value higher than the average respondent. Also noteworthy, this group rates legislation as being the 3rd strongest advantage of HFC-free solutions. This points to investment security, given that existing and expected legislation against high-global warming potential gases will leave the natural refrigerant industry unconcerned.

ENVIRONMENT CLEAREST BENEFIT; SYSTEM COSTS REMAIN CHALLENGE

QUESTION: "What are the biggest strengths of Natural Refrigerant applications?" - average values



When all strengths are shown as a weighted average, environmental direct and indirect benefits remain the top score for natural refrigerants' strengths. On par are the four factors of operation costs, technology, legislation and markets & competition. System costs are considered to be the weakest strength which reconfirms findings from the barriers section in that newly introduced natural refrigerant technology is not yet able to compete with traditional systems on grounds of capital cost.

A SWOT ANALYSIS FOR NATURAL REFRIGERANTS IN EUROPE

511 participants from organisations located in Europe responded to questions about the major challenges ("What are the biggest barriers in adopting Natural Refrigerants?") for and the dominant strengths ("What are the biggest strengths of Natural Refrigerants?") of HFC-free working fluids. Respondents could rate seven predefined categories of barriers and strengths according to their impact on the market uptake of natural refrigerants. The four response options per category ranged from "no barrier" to "very strong barrier", and from "no strength" to "very high strength", respectively. An additional free text field collected responses to further explain the perceived challenges and benefits for individual countries and/or application fields.

BARRIERS

With 58% of respondents saying **Training & Know-how** constitutes a "high" or "very high" barrier, the lack of appropriate skills among installers and maintenance personnel in contact with ammonia, hydrocarbons and carbon dioxide is the most important single barrier to a wider acceptance of natural refrigerants. No common certification scheme and still only a loose network of training bodies has made the handling of refrigerants with toxicity, flammability and high pressure characteristics a challenge to be overcome only by more streamlined activities between industry, policy and end-users.

This point is also directly related to the second strongest challenge - **Technology & Safety** - where different safety rules across Europe, together with the novelty of NR technology in some fields, will continue posing a challenge to HFC-free technology proponents. This category is, however, less pronounced than the training aspect (49% rating it as a high / very high barrier), given that some technologies have already become standard solutions. As examples may serve the use of HC in domestic and light-commercial refrigeration, NH_3 in industrial refrigeration or CO_2 in commercial refrigeration.

Psychology - describing a lack of awareness and acceptance, as well as misconceptions about NR solutions - is the 3rd strongest barrier when weighted across all response options. Only 20% of respondents feel that "no" or only "minor" barriers exist in this area, the rest facing difficulties in overcoming these non-technical barriers. This, again, confirms that a lack of knowledge, especially among customers and the traditional HVAC&R industry overall, exists (see pages 92 to 93). It can be concluded that whereas technical challenges can and will be gradually resolved, psychological barriers will need to be addressed separately in a joint effort by international and national bodies, the industry and (industrial and private) end-users.

STRENGTHS

With an overwhelming 81% vote as a "high" or "very high" strength, **Environment** remains the single most important reason to opt for f-gases free heating, air-conditioning or refrigeration solutions. The environmental aspect does not only include zero to low global warming impact from direct natural refrigerant emissions, but also encompasses indirect emissions reductions through higher energy efficiency as compared to traditional solutions, especially when looked at the technology in its whole lifecycle. While the competitive advantage of NR systems has been clearly demonstrated in a variety of sectors already, the constant new development of HFC-free solutions still promises high future technology potential – something that has been found to be more restricted for current systems based on synthetic working fluids.

As the second largest overall strength of HC, NH_3 and CO_2 systems, **Operation Costs** are confirmed by half of all respondents (50%) as being a strong to very strong benefit. This, however is in stark contrast to System Costs at the farther end of the scale where only 16% can confirm that the required initial financial investment for NR solutions can already today compete with established f-gases solutions. From the resulting response pattern it can be concluded that although the price premium to be paid for a majority of natural refrigerant installations can be recovered over the system's lifetime, the higher costs up front constitute a strong barrier to higher sales of NR solutions, given consumers' time preference or "discount rate" on purchases.

STRENGTHS VS. BARRIERS

If we compare the response sets for the sections on barriers and strengths, some interesting results can be obtained. Whereas respondents rated **Supply & Availability** to be the second least important barrier to the uptake of natural refrigerant systems, the exact same is true when being asked for their strength. This could confirm that NR systems have been established as mainstream solutions in Europe in some areas – domestic and industrial refrigeration, and increasingly also in cascade solutions for commercial refrigeration – whereas a significant number of other applications still faces shortage of supply and viable technology options. The evaluation of this aspect hence mainly depends on the market the respondent is in and whether he/she encounters any difficulties in obtaining appropriate components and/or systems.

Another interesting item is the evaluation of the **Technology & Safety** aspect. Whereas 50% of all responses say that this issue constitutes a high or very high barrier for NR systems, 40% also confirm that "technology" – including durability & reliability, compactness & weight, efficiency – is the 3rd strongest benefit of NR options (high / very high strength). A possible explanation for

this seemingly contradicting result is that a lack of uniform safety guidelines & standards in combination with no certified installation and maintenance staff across European countries, together with remaining technology challenges has significantly reduced the speed of market adoption. On the other hand, once technology is put into place customer satisfaction rates have been generally high due to efficiency gains, ease of maintenance and high operational reliability of NR systems.

Clearly confirmed as a major barrier is the **Capital Cost** aspect. Coupled with the generally applicable principle of facing a price premium for the first use of new technologies, due to their lack of economies of scale, natural refrigerant solutions in some areas require completely new system layouts, components and materials. It is hence not surprising that a clear absolute majority of 54% consider "system costs" (production, materials, refrigerants, installation, government support) to be "no" or only a "minor" strength of NR systems at this moment, and that 45% rate "funding & costs" (taxes, subsidies) as a high to very high barrier to a faster market uptake.

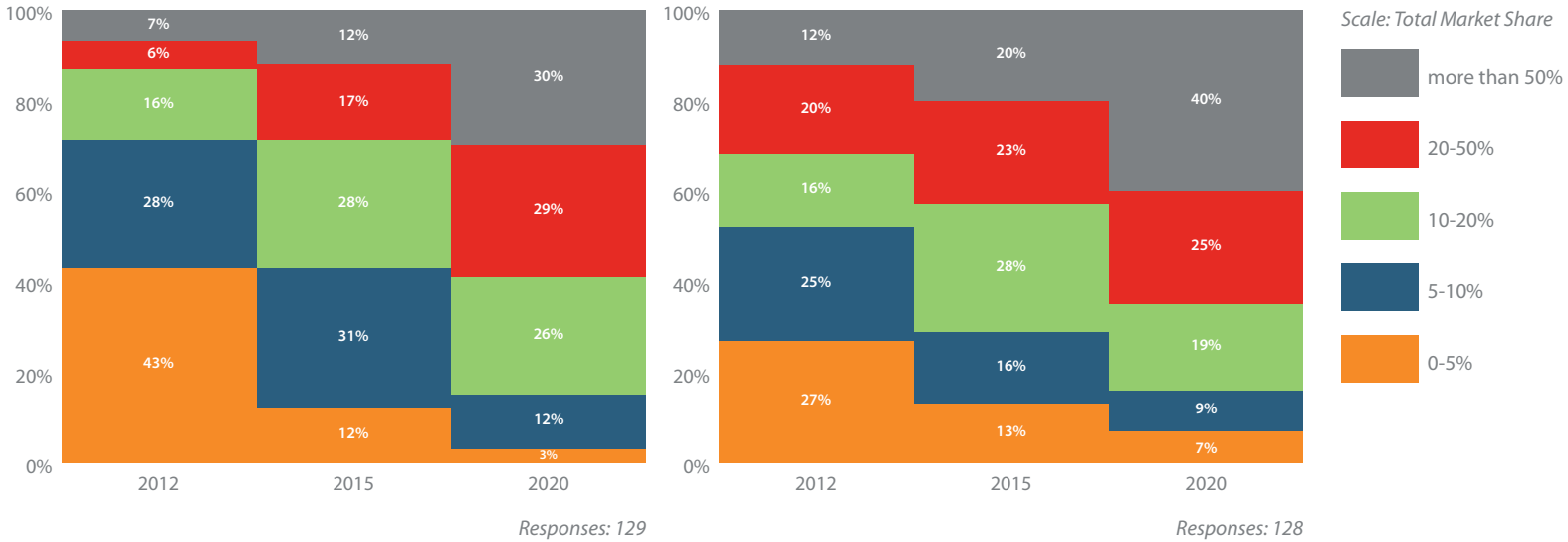
However, this is partly balanced by the assumption that reductions in **Life-Cycle Costs** are superior to traditional systems. Half of all respondents (50%) state that lower "operation costs" – including energy savings, operation, maintenance and end-of-life treatment – are a high to very high benefit of NR systems.

Markets (Competition & Demand) play a minor role in accelerating or slowing down the uptake of HFC-free solutions. This has evolved over the last few years when respondents in the NR industry considered competition by traditional systems to be a major challenge for introducing new technology. As a result it is now the least important barrier mentioned, with 69% saying it is "no" to only a "moderate" barrier. Similarly, only 1/10 of respondents see "markets & competition" - including "green" marketing, CSR (Coporate Social Responsability) and other competitive advantages - as a "very high" strength of NR solutions. This could confirm that, although environmental benefits are the most important driver to move away from fluorinated gases, the competitive advantage of NR solutions has not yet been fully exploited to become a major market driver.

NATURAL REFRIGERANTS INDUSTRY EXPECTATIONS

REFRIGERATION

QUESTION: "What will be the market share of Natural Refrigerant systems in 2012, 2015 and 2020?"



COMMERCIAL REFRIGERATION

Europe's NR industry expects the market share of commercial refrigeration equipment using CO_2, NH_3 or HCs to increase substantially over the coming years. While today still 43% of the 129 respondents working in the commercial refrigeration business estimate the total market share of NR solutions to be only in the range of 0-5%, by 2020 this picture is inverted, with 30% stating that their share would increase to "more than 50%". As a result, only 3% think NR systems' market share will remain in the "0-5%" order.

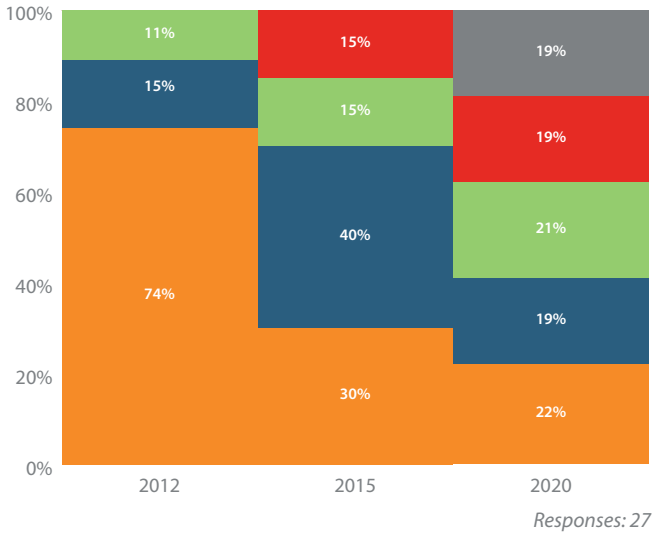
INDUSTRIAL REFRIGERATION

An even more prosperous outlook is presented for the industrial refrigeration sector. 40% of 128 respondents working in this field believe that the NR market share will rise to "more than 50%" by 2020. This is up from 12% estimating the market share to be in this range already today. By 2015, a total of 43% estimate the market share of NR systems already to be on track for "20-50%" or "above 50%".

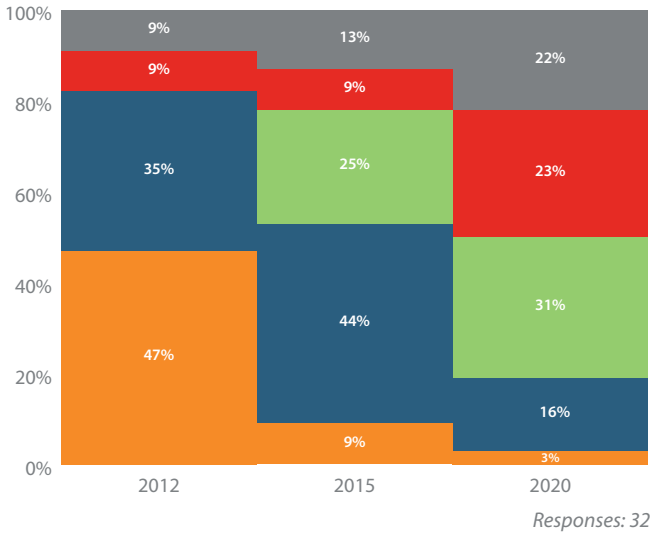
NATURAL REFRIGERANTS INDUSTRY EXPECTATIONS

HEATING

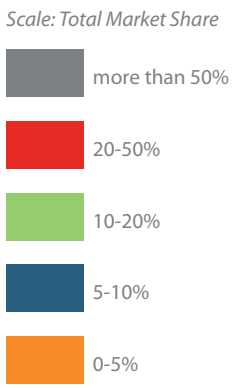
QUESTION: "What will be the market share of Natural Refrigerant systems in 2012, 2015 and 2020?"



Responses: 27



Responses: 32



RESIDENTIAL HEATING

Today, the market share of NR solutions in Europe is only minute, nearly two-thirds of 27 respondents working in residential heating confirm. However, while the "more than 50%" market share is missing for 2012, by 2020 systems using CO_2, NH_3 or HC will have established themselves. As a result, 19% believe that NR solutions will dominate the market, while 22% remain cautious to believe that NR products will remain a tiny fraction of the market ("0-5%").

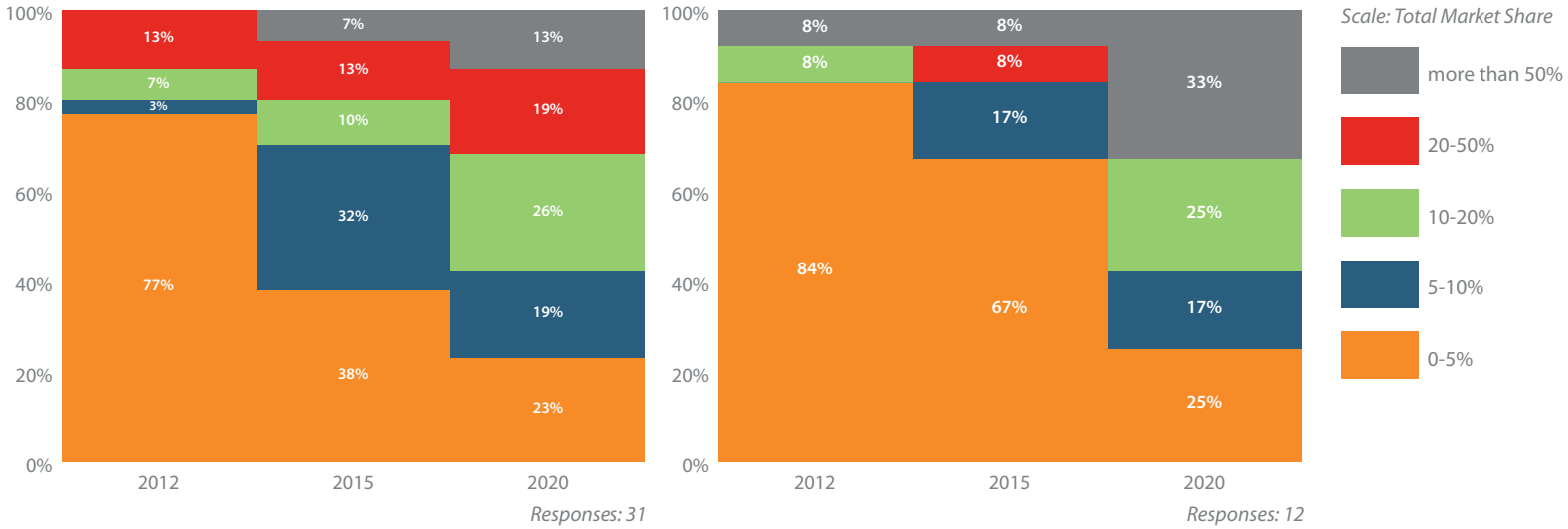
COMMERCIAL & INDUSTRIAL HEATING

More optimistic than their residential heating counterparts are the 32 natural refrigerants experts representing the commercial and industrial heating industry in Europe. 22% believe that NR solutions' market share will have increased to "more than 50%" by 2020, up from 9% saying that today. On the other hand, only 19% remain sceptical and assume the market penetration to be still below 10% (responses: "0-5%" and "5-10%") by that time - down from a large majority of 82% saying this is true for today's markets.

NATURAL REFRIGERANTS INDUSTRY EXPECTATIONS

AIR-CONDITIONING

QUESTION: "What will be the market share of Natural Refrigerant systems in 2012, 2015 and 2020?"



STATIONARY AIR CONDITIONING

The 31 experts for stationary air-conditioning involving natural refrigerants show the highest scepticism of all surveyed participants for the medium future, with only 13% believing that NR systems would have a "20% -50%" share in 2020. However, on the other hand, response rate for any NR market share higher than 10% nearly triples from 20% in 2012 to 58% in 2020.

MOBILE AIR CONDITIONING

With the highest number of responses (84%) opting for a "0-5%" market share in 2012, the MAC industry is the most challenging out of all sub-sectors surveyed. However, interestingly the industry seems to be optimistic for 2020, with one-third of respondents believing in a "50% or higher" market share of NR systems. However, one should note that results have only limited informative value due to a very low response rate. Only 12 individuals offering or planning to offer NR solutions in MAC responded to the survey, suggesting that as development of CO_2 and HC systems is largely put on hold.

MARKET FORECASTS 2012–2020

MARKET FORECASTS 2012-2020

The global industry survey conducted between February and September 2011 intended, for the first time, to hear the voice of the HVAC&R industry in general and the natural refrigerant sector in particular regarding their market expectations for the coming years. Out of a total response set of 666 individuals being located in Europe, 359 were selected for further analysis. This smaller sub-set encompassed all those already using and/or planning to use carbon dioxide, ammonia or hydrocarbons in their products and services. While the first part of the survey was the same for all respondents, for the second survey part individuals had to select their field of expertise among 8 industry sectors: Heating (Residential & Building), Heating (Industrial & Commercial), Refrigeration (Domestic), Refrigeration (Commercial), Refrigeration (Industrial), Refrigeration (Transport), Air Conditioning (Stationary), and Air Conditioning (Mobile). Transport refrigeration and domestic refrigeration were excluded in the final results due to a lack of data accuracy.

All other industry sectors were represented to different extents, ranging from 12 individuals working on NR-based Mobile Air Conditioning (MAC) to 129 respondents for Commercial Refrigeration. The high response rate for the commercial and industrial refrigeration sectors (128 responses) confirmed the lead role these two sub-sectors currently play for the market growth of natural refrigerants in Europe. Especially the use of CO_2 in cascade and transcritical supermarket systems, the use of hydrocarbons in light-commercial installations, and the use of NH_3 in industrial refrigeration (with CO_2 and HC gaining market share) are driving the market. On the other end of the spectrum, only 12 respondents for the MAC sector testify that where the use of CO_2 and HCs has been stalled for the near future – largely due to the automotive industry's decision to opt for synthetic refrigerant alternatives – R&D activities inside the industry have dropped.

THE GROWTH MARKETS

The sectors with the highest response rates, commercial refrigeration and industrial refrigeration, are also those facing the brightest future, according to NR experts. A clear majority of 65% are sure that natural refrigerant alternatives in industrial refrigeration will have a higher than 20% market share in Europe by 2020. The commercial refrigeration industry is similarly optimistic, where 59% believe that NR systems will make up at least a fourth of the total market, and 30% targeting a market penetration of even "50% or higher". Interestingly, the commercial refrigeration industry comes from a much smaller baseline than their industrial counterparts: Only 13% of commercial refrigeration experts say that NR options currently have a 20%+ market share, whereas 32% confirm this for the industrial refrigeration market to be true today. Assumed relative growth rates are hence bigger for the commercial sector, where the agreement rate for a 20%+ market share more than doubles for each of the three periods (2012, 2015, 2020) to get very close to the 2020 agreement rate in the industrial refrigeration sector.

THE "OPEN" MARKETS

Both the residential heating and stationary air conditioning sector seem to be undecided regarding the market share to expect for NR solutions in the medium future. A very regular response pattern can hence be found for the 31 stationary A/C and 27 residential heating experts evaluating the situation for 2020. Especially for the latter, all options, ranging from a "0-5%" to a "50% or higher" market share, attract the same level of agreement. The only marked difference between the two industry sectors is the higher baseline the stationary A/C industry is building on, with 13% stating that already today natural refrigerants have a 50%+ market share. However, on the other hand, the residential heating market will, according to experts representing it, overtake the stationary air-conditioning market by 2020 in terms of relative market shares.

THE "WAITING" MARKETS

The natural refrigerant Mobile Air Conditioning sector currently faces some of the strongest resistance in the European Union. Despite the positive frameworks put into place by the MAC Directive (see page 46), R&D activities are mostly stalled after years of successfully introducing market-ready solutions. 84% of respondents saying there is a close to 0% market penetration of NR systems today is hence unsurprising. More interesting are, however, expectations for 2020 when a third of respondents regard again a "50% or higher" market share as being possible. This points to the fact that either direct intervention from legislators or a clear "recommitment" of the automotive industry in favour of HFC-free systems would be needed to initiate market growth. Again, it has to be noted that total responses for the MAC sector were at a very low level as compared to other industries represented, hence not allowing for a highly accurate data analysis. It might, however, serve as a first indication of the industry's current situation with no positive signals sent from the automotive industry to use carbon dioxide or hydrocarbons. Transport applications outside the car sector (buses, trains, trucks) still promise growth potential.

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DENMARK

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GERMANY

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UK

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DIRECTORY

Without wide availability and broad market acceptance an innovation will not be recognised as such. End-users, legislators and the wider public need to know about solutions offered today and technology pioneers involved, to make an informed choice about future refrigerant options. Without a strong industry network the impact of natural refrigerants will remain limited in certain applications.

This industry directory, based largely on responses to an HVAC&R industry survey, lists and categorises system manufacturers, component suppliers, contractors, installers, and research & training institutes located in Europe. 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 organisations, no responsibility for accuracy is assumed.

If you want to be included in later editions of the *Guide - 2012: Natural Refrigerants Market Growth for Europe* or other world regions, please contact *research@shecco.com*

AUSTRIA

FRIGOPOL – KÄLTEANLAGEN GMBH
www.frigopol.com

Manufacturer
Supplier

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

Kälteanlagen GmbH, Gamser Str. 21,
A-8523 Frauental a.d.L, Austria

+43 (0) 3462 70 000

CO_2 HC NH_3

KWN ENGINEERING GESELLSCHAFT MBH
www. kwn.at

Engineering / Contractor

Refrigeration - Industrial

Bernd Kaltenbrunner, Sommerweg 13
A-5201 Seekirchen, Austria

+43 (0) 6212 7833

CO_2 HC NH_3

OBRIST
www.obrist.at

Engineering / Contracting

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

Rheinstrasse 26-27
A-6890 Lustenau, Austria

+43 (0) 55 77 623 70 0

CO_2 HC NH_3

VENTREX
www.ventrex.com
Supplier

Air Conditioning - Mobile

Johann Sebastian Bach Gasse 1
A-8010 Graz, Austria

+43 316 4676 0

CO_2 HC NH_3

BELGIUM

AFM EUROP
www.afm-europ.com

Manufacturer
Supplier

Refrigeration - Commercial
Air Conditioning - Stationary

AFM Bvba, Singel 4a,
2550 Kontich, Belgium

+32 (0) 3/458 29 58

CO_2 HC NH_3

BALTIMORE AIRCOIL INTERNATIONAL EU
www.baltimoreaircoil.be

Manufacturer

Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Stationary
Industrial Process Cooling
District Cooling
Industriepark

2220 Heist-op-den-berg, Belgium

+32 15 257 710

CO_2 HC NH_3

ECO-FREEZE
www.eco-freeze.com

Manufacturer

Heating - Industrial & Commercial
Refrigeration - Commercial
Air Conditioning - Mobile
Fluid supply

Sint Bernardsesteenweg 635-637
2660 Antwerp, Belgium

+ 32 3 294 69 87

CO_2 HC NH_3

EVAPCO EU
www.evapco.be

Manufacturer
Supplier

Refrigeration - Industrial
Air Conditioning - Stationary

Industrieterrein Oost 4010
Tongeren, Belgium

+32 12 39 50 29

CO_2 HC NH_3

ITE N.V.
www.ite-tools.com

Supplier

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

Europark Oost 24
9100 Sint Niklaas, Belgium

+32 37 66 02 02

CO_2 HC NH_3

MASTER COOL
www.mastercool.com

Engineering / Contractor

Refrigeration - Commercial
Refrigeration - Industrial

Europark Noord 14b
9100 Sint Niklaas, Belgium

+32 3 777 28 48

CO_2 HC NH_3

MAYEKAWA
www.mayekawa.co.jp

Manufacturer

Refrigeration - Industrial

Leuvensesteenweg 605
1930 Zaventem, Belgium

+32 2 757 90 75

CO_2 HC NH_3

SABCOBEL
www.sabcobel.be

Engineering / Contractor

Refrigeration - Commercial
Refrigeration - Industrial

Industriepark-West 62
9100 Sint-Niklaas, Belgium

+32 3 780 77 77

CO_2 ~~HC~~ ~~NH_3~~

BULGARIA

BG CLIMA LTD.
www.bgclima.eu

Manufacturer
Supplier

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

11 Dunav Street,
1000 Sofia, Bulgaria

+359 2 989 20 85

CO_2 HC ~~NH_3~~

FRAMO
www.frigus.bg

Manufacturer

Engineering / Contractor
Refrigeration - Commercial

Parva bulgarska armia 18A
1220 Sofia, Bulgaria

+359 2 813 99 11

CO_2 HC NH_3

CYPRUS

ME. E. BEST COOL LTD
www.primetel.com.cy

Engineering / Contractor

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

76A Georgiou Griva Digeni
4043 Lemesos, Cyprus

+35 725 58 07 88

CO_2 HC NH_3

CZECH REPUBLIC

ECT
www.emerson.com

Manufacturer
Engineering / Contractor

Refrigeration - Commercial

K Vapence
69201 Mikulov, Czech Republic

+42 051 900 00 00

CO_2 HC NH_3

DENMARK

ADVANSOR A/S
www.advansor.dk

Manufacturer

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

Bautavej 1A
8210 Aarhus , Denmark

+45 41 19 30 05

CO_2 HC NH_3

AGRAMKOW FLUID SYSTEMS A/S
www.agramkow.com

Supplier

Engineering / Contractor
Refrigeration - Domestic
Refrigeration - Commercial
Air Conditioning - Stationary

Augustenborg Landevej 19
6200 Sonderborg , Denmark

+45 74 12 35 36

CO_2 HC NH_3

BUNDGAARD KØLETEKNIK A/S
www.chillers.dk

Manufacturer
Supplier

Heating - Industrial & Commercial
Air Conditioning - Stationary

Bundgaard Køleteknik A/S
Sadelmagervej 22
7100 Vejle , Denmark

+45 75 85 73 11

CO_2 HC NH_3

CARAVELL
www.caravell.dk

Manufacturer
Supplier
Refrigeration - Commercial

Testrupvej 5 DK-9620
9620 Aalestrup, Denmark

+45 9666 1800

CO_2 HC NH_3

DANFOSS
www.danfoss.com

Manufacturer
Supplier
Heating - Residential & Building
Heating - Industrial & Commercia
Refrigeration - Domestic
Refrigeration - Commercial
Refrigeration - Industrial
Refrigeration - Transport
Air Conditioning - Stationary

Jegstrupvej 3
8361 Hasselager , Denmark

+45 24 11 91 49

CO_2 HC NH_3

DANISH TECHNOLOGICAL INSTITUTE
www.dti.dk

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

Kongsvang Alle 29
8000 Aarhus , Denmark

+45 72 20 20 37

CO_2 HC NH_3

DSI
www.dsi-as.com

Manufacturer
Supplier

Refrigeration - Industrial

Parkvej 5
9352 Dybvad, Denmark

+45 98 86 42 99

CO_2 NH_3

GERSTENBERG SCHRÖDER
www.gs-as.com

Manufacturer

Refrigeration - Industrial

Oestmarken 7
2860 Soeborg, Denmark

+45 70 27 82 22

CO_2 NH_3

GRAM REFRIGERATION
www.gram-commercial.com

Manufacturer
Supplier

Refrigeration - Commercial

Aage Grams Vej 1
6500 Vojens, Denmark

+45 73 20 12 00

HC

GRUNDFOS
www.grundfos.com

Manufacturer

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

Poul Due Jensens Vej 7
8850 Bjerringbro, Denmark

+45 29 38 29 54

CO_2 NH_3

H. JESSEN JÜRGENSEN A/S
www.hjj.dk

Wholesaler

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

Tempovej 18-22
2750 Ballerup, Denmark

+45 44 20 06 03

CO_2 HC NH_3

HB PRODUCTS A/S
www.hbproducts.dk

Supplier

Refrigeration - Commercial
Refrigeration - Industrial

Bøgekildevej 21
8361 Hasselager, Denmark

+45 87 47 62 07

CO_2 HC NH_3

INNOTEK
www.innotek.dk

Manufacturer
Supplier
Consultancy / Marketing
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Stationary

Essen 10
6000 Kolding, Denmark

+45 70 20 23 43

CO_2 HC NH_3

JOHNSON CONTROLS
www.jci.com

Manufacturer

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

Christian D.X's Vej 201
8270 Hoejbjerg, Denmark

+45 29 22 71 59

CO_2 HC NH_3

KNUDSEN KØLING
www.knudsenkoling.dk

Supplier

Refrigeration - Commercial

Sandvadsvej 5
4600 Køge, Denmark

+45 56 64 63 50

CO_2 NH_3

KUVATEK
www.kuvatek.dk

Manufacturer

Refrigeration - Commercial

KUVATEK A/S
Parallelvej 2
9870 Sindal, Denmark

+ 45 65 96 77 96

METALFRIO SOLUTIONS A/S
www.metalfrio.dk

Manufacturer
Supplier

Refrigeration - Commercial

Metalfrio Solutions A/S, Testrupvj 5
9620 Aalestrup, Denmark

+45 96 66 19 02

PG FLOWTEKNIK SCANDINAVIA APS
www.pgflowteknik.dk

Manufacturer
Supplier

Refrigeration - Commercial
Refrigeration - Industrial

Snedkervej 12
2630 Tåstrup, Denmark

+45 73 84 12 30

SVEDAN INDUSTRI KOELANLAEG A-S
www.svedan.com

Manufacturer

Engineering / Contractor
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Stationary

Haandvaerkerbyen 8
2760 Greve, Denmark

+45 43 90 71 11

VESTFROST
www.vestfrost.dk

Manufacturer
Supplier

Refrigeration - Domestic
Refrigeration - Commercial

Spangsbjerg Møllevej 100
6705 Esbjerg Ø, Denmark

+45 76 10 40 45

FINLAND

AX CONSULTING LTD
www.ax.fi

Engineering / Contractor
Consultancy / Marketing

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

Kuokkamaantie 4
33101 Tampere, Finland

+ 358 32 68 01 11

FINESS ENERGY LTD
www.finess.fi

Manufacturer
Supplier
Engineering / Contractor

Heating - Industrial & Commercial
Refrigeration - Industrial

Läntinen Pitkäkatu 21-23 A
20100 Turku, Finland

+358 40 20 00 00 0

HUURRE GROUP OY
www.huurre.com

Manufacturer
Engineering / Contractor
Consultancy / Marketing
Training / Research
Service and maintenance provider

Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Stationary

Taivaltie 5
1610 Vantaa, Finland

+358 40 60 00 00 0

KESKO OY
www.kesko.fi

retail market

satamakatu 3
16 helsinki, Finland

+358 50 40 00 00 0

CO_2 HC NH_3

SCANCOOL
www.scancool.fi

Manufacturer
Supplier
Engineering / Contractor

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

Yrittäjäntie 6
67100 Kokkola, Finland

+ 358 40 86 13 00 5

CO_2 HC NH_3

FRANCE

AXIMA REFRIGERATION
www.aximaref.com

Manufacturer
Supplier

Refrigeration - Domestic
Refrigeration - Commercial
Refrigeration - Industrial

6 rue de l'atome
67800 Bisheim, France

+33 3 88 19 19 00

CO_2 HC NH_3

CARLY
www.carly-sa.com

Manufacturer
Supplier

ZI de Braille
69380 Lissieu, France

+33 (0) 4 78 47 61 20

CO_2 HC NH_3

CETIM
www.cetim.fr

Engineering / Contractor
Consultancy / Marketing
Containment specialists

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

74 route de la Joneliere
44100 Nantes, France

+33 (0) 24 03 73 645

CO_2 HC NH_3

CIAT
www.ciat.fr

Manufacturer

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

2 avenue Jean Falconnier BP14
1350 Culoz, France

+33 4 79 42 62 68

CO_2 HC NH_3

GFF (Groupe BEIJER REF)
www.beijers.com

distributor

Heating - Industrial & Commercial
Refrigeration - Commercial

12 rue des Frères Lumieres
69720 St Bonnet De Mure, France

+33 4 72 48 30 00

CO_2 HC NH_3

PAUMIER
www.ets-paumier.fr

Manufacturer
Engineering / Contractor

Refrigeration - Industrial / Transport
Air Conditioning - Stationary / Mobile

Parc d'Activités des Hautes Falaises
76400 Fécamp, France

+33 23 51 02 350

CO_2 HC NH_3

POLE CRISTAL
www.pole-cristal.tm.fr

Association

Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Stationary

48, Promenade de la Fontain des Eaux
22100 Dinan, France

+33 2 96 87 20 00

CO_2 HC NH_3

SANDEN MANUFACTURING EUROPE
www.sanden-europe.com

Manufacturer
Engineering / Contractor

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

Le Quilliou
35190 Tinténiac, France

+33 2 99 45 58 58

CO_2 HC NH_3

TECUMSEH EUROPE
www.tecumseh.com

Manufacturer

Engineering / Contractor
compressors & condensing unit
Refrigeration - Commercial

2 avenue Blaise Pascal
38090 Vaulx Milieu, France

+33 474 822 400

CO_2 HC NH_3

GERMANY

ALPHA INNOTEC GMBH
www.alpha-innotec.de

Manufacturer

Heating - Residential & Building
Heating - Industrial & Commercial

Industriestrasse 3
95359 Kasendor, Germany

+49 922 900 000 00

CO_2 HC NH_3

ARMATURENWERK ALTENBURG
www.awa-armaturenwerk.de

Supplier

Refrigeration - Commercial
Air Conditioning - Stationary

Am Weißen Berg 30
4600 Altenburg, Germany

+49 (0) 3447 / 893-0

CO_2 HC NH_3

BITZER
www.bitzer.de

Supplier

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

Eshenbrunnlestrasse15
71065 Sindelfingen, Germany

+49 70 3193 20

CO_2 HC NH_3

BOCK KÄLTEMASCHINEN GMBH
www.bock.de

Supplier

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

Benzstraße 7
72636 Frickenhausen, Germany

+49 7022 94 54 159

CO_2 HC NH_3

CABERO
www.cabero.de

Manufacturer
Supplier

Heating - Industrial & Commercial
Refrigeration - Commercial
Refrigeration - Industrial

Jesenwanger Straße 50
82284 Grafrath, Germany

+49 8144 9396-0

CO_2 HC NH_3

CARRIER COMMERCIAL REFRIGERATION
www.carrier-refrigeration.com

Manufacturer
Engineering / Contractor

Consultancy / Marketing
Refrigeration - Commercial
Refrigeration - Industrial

Suerther Hauptstrasse 173
50999 Cologne, Germany

+49 89 32 15 40

CO_2 HC NH_3

DAIKIN GERMANY

www.daikin.de

Manufacturer
sales of manfufaturer

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

Inselkammerstr.
82008 Unterhaching, Germany

+49 17 29 00 00 00

CO_2 HC NH_3

EMERSON

www.emerson.com

Manufacturer

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

Pascalstrasse 65
52076 Aachen, Germany

+49 24 08 92 90

CO_2 HC NH_3

ESK SCHULTZE

www.esk-schultze.de

Manufacturer

Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Mobile

Parkallee 8

16727 Velten, Germany

+49 3304 3903 0

CO_2 HC NH_3

FREUDENBERG

www.fst.com/ecomaXL/

Supplier

Air Conditioning - Mobile

Höhnerweg 2-4
69465 Weinheim/Bergstraße, Germany

+49 (0) 6201 - 80 - 6666

CO_2 HC NH_3

FUTRON

www.futron.de

Manufacturer
Supplier
Engineering / Contractor

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

Elisabethstraße 29
08491 Netzschkau, Germany

CO_2 HC NH_3

GEA

www.geagroup.com

Manufacturer

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

Peter-Müller straße 12
40468 Dusseldorf, Germany

+49 21 19 13 60

CO_2 HC NH_3

GFKK GESELLSCHAFT FÜR KÄLTETECHNIK - KLIMATECHNIK MBH

www.gfkk.de

Supplier

Engineering / Contractor
Refrigeration - Industrial
Air Conditioning - Stationary

Dieselstr. 7
50859 Köln, Germany
+49 (0) 2234 / 40060

CO_2 HC NH_3

GRUNDFOS GMBH

www.grundfos.de

Manufacturer
Supplier

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

Schlüterstr. 33
40699 Erkrath, Germany

CO_2 HC NH_3

GUENTNER AG & CO.KG

www.guentner.de

Supplier

Refrigeration - Commercial
Refrigeration - Industrial

Germany

CO_2 HC NH_3

HAAS ANLAGENBAU GMBH
www.anlagenbauhaas.de

Supplier
Engineering / Contractor

Refrigeration - Industrial

Eichfeldstr. 22
83339 Chieming/Egerer, Germany

+49 (0) 8664 / 98 880

CO_2 HC NH_3

HEIFO RÜTERBORIES GMBH & CO. KG
www.heifo.de

Manufacturer
Supplier
Engineering / Contractor

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

Hannoversche Str.49
49084 Osnabrück, Germany

+49 54 15 84 32 46

CO_2 HC NH_3

HERL (Parker)
www.herl.de

Heating - Industrial & Commercial
Refrigeration - Industrial

Wankelstraße 40
50996 Köln, Germany

+49 02236 39 00 0

CO_2 HC NH_3

HKT GMBH
www.hkt-goeldner.de

Supplier

Refrigeration - Domestic
Refrigeration - Commercial
Refrigeration - Industrial

83128 Halfing, Germany

+49 (0) 8055 9187

CO_2 HC NH_3

ILK DRESDEN
www.ilkdresden.de

R&D

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

Bertoit-Brecht-Allee 20
01309 Dresden, Germany
+49 351 4081 520

CO_2 HC NH_3

INFICON
www.inficon.com

Supplier

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

Germany

CO_2 HC NH_3

INSTITUT FÜR KÄLTE, KLIMA UND UMWELTTECHNIK
www.hs-karlsruhe.de

Consultancy / Marketing
Training / Research
University

Fakultät für Maschinenbau und Mechatronik
Hochschule Karlsruhe Technik und Wirtschaft
Moltkestr. 30
76133 Karlsruhe, Germany

+49 721 925 1914

CO_2 HC NH_3

IXETIC
www.ixetic.com

Supplier

Air Conditioning - Mobile
heating mobile

Georg-Schaefflerstraße 1
42499 Hückeswagen, Germany

+49 21 22 85 20

CO_2 HC NH_3

KACO GMBH&CO. KG
www.kaco.de

Manufacturer
Supplier

Air Conditioning - Mobile

Heilbronnerstraße 11
74388 Talheim, Germany
+49 71 34 00 00 00

CO_2 HC NH_3

KAELTEFISCHER
www.kaeltefischer.de

Supplier
Engineering / Contractor

Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Stationary
Refrigerants + controllers

Christof Fischer GmbH Hauptsitz
Augsburger Str. 289-293
70327 Stuttgart, Germany

+49 (07 11) 30 50 2 - 0

CO_2 HC NH_3

KÄLTETECHNIK DRESEN BREMEN GMBH
www.dresenkaelte.de

Supplier
Engineering / Contractor

Refrigeration - Industrial
Air Conditioning - Stationary

Waller Esch 3,
49594 Alfhausen, Germany

+49 (0) 5464 96 10 0

CO_2 HC NH_3

KKE-SYSTEMTECHNISCHE BERATUNG
www.kke-system.de

Engineering / Contractor
Consultancy / Marketing

Heating - Residential & Building
Refrigeration - Commercial
Refrigeration - Industrial

Grüner Weg 5a
35625 Hüttenberg,Germany

+49 6447 230

CO_2 HC NH_3

KONVEKTA AG
www.konvekta.com

Manufacturer
Supplier

Refrigeration - Transport
Air Conditioning - Mobile

Am Nordbahnhof 5
34613 Schwalmstadt, Germany

+49 66 91 76 219

CO_2 HC NH_3

KREUTZTRÄGER KÄLTETECHNIK GMBH & CO. KG
www.kreutztraeger.de

Supplier
Engineering / Contractor

Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Stationary
Air Conditioning - Large Stationary

TheodorBarthStr. 21
28307 Bremen Germany

+49 (0) 421 43867 0

CO_2 HC NH_3

LINDE
www.linde.com

Manufacturer
Supplier

Refrigeration - Domestic
Refrigeration - Commercial
Refrigeration - Transport
Air Conditioning - Stationary
Air Conditioning - Mobile
Manufacturer and distributor of refrigerants and some related equipment

The Priestley Centre
GU2 7XY Guildford, Germany

+44 77 70 80 33

CO_2 HC NH_3

M-TEC
www.m-tec.com

Supplier

Heat pump installer, refrigeration and aircondition
Heating - Residential & Building
Heating - Industrial & Commercial
Refrigeration - Domestic
Refrigeration - Commercial
heat recovery industrial and commercial

Otto-Hahnstraße 6
79395 Nuenburg, Germany
+49 76 31 70 90

CO_2 HC NH_3

MAJA
www.maja.de

Manufacturer

Refrigeration - Commercial

Tullastr. 4
77694 Kehl-Goldscheuer, Germany

+49 7854 184 0

CO_2 HC NH_3

PETER HUBER KÄLTEMASCHINENBAU GMBH
www.huber-online.com

Manufacturer

Refrigeration - Industrial

Werner von Siemens Strasse 1
77656 Offenburg, Germany

+49 (0) 781 9603 0

CO_2 HC NH_3

REFRIGERANTS, NATURALLY!
www.refrigerantsnaturally.org

Association

Refrigeration - Commercial

Zum Talblick 2
61479 Glashuetten, Germany

+49 6174 964077

CO_2 HC NH_3

SCHICK GMBH + CO. KG
www.schickgruppe.de

Manufacturer
Supplier

Gas supply

Tafingerstr. 4
71665 Vaihingen/Enz, Germany

+49 (0) 7042 95 35 0

CO_2 HC NH_3

SCHICK GRUPPE
www.schickemzet.de

Supplier
Consultancy / Marketing

Distribution of ammonia and refrigerants

71665 Vaihingen/Enz, Germany
+49 70 42 95 35 0

CO_2 HC NH_3

SPECK TRIPLEX
www.speck-triplex.de

Manufacturer

High pressure plunger pumps

Speck Triplex GmbH & Co KG
Walkenweg 41
33609 Bielefeld, Germany

+49 (0)521 970 48 0

CO_2 HC NH_3

TEKO
www.teko-kaeltetechnik.com

Manufacturer
Supplier

Refrigeration - Commercial
Air Conditioning - Stationary
Air Conditioning - Large Stationary

TEKO Gesellschaft für Kältetechnik mbH
Carl-Benz-Straße 1
63674 Altenstadt, Germany

+49 (0) 60 47 96 30 0

CO_2 HC NH_3

TH. WITT KÄLTEMASCHINENFABRIK GMBH
www.th-witt.com

Manufacturer
Supplier

Engineering / Contractor
Refrigeration - Industrial

Lukasstr. 32
52070 Aachen, Germany

+49 (0) 241 / 1 82 080

CO_2 HC NH_3

THERMEA
www.thermea.de

Manufacturer
Supplier

Engineering / Contractor
Heating - Industrial

thermea. Energy Systems GmbH
Poisentalstaße 75
01705 Freital, Germany

+49 (0) 351 640 150

CO_2 HC NH_3

THERMOFIN GMBH
www.thermofin.de

Supplier
Engineering / Contractor

Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Stationary
Air Conditioning - Large Stationary

Am Windrad 1
08468 Heinsdorfergrund, Germany

+49 (0)37 65 38 000

CO_2 HC NH_3

THERMOWAVE GESELLSCHAFT FÜR WÄRMETECHNIK MBH
www.thermowave.de

Supplier
Refrigeration - Commercial

Refrigeration - Industrial

Eichenweg 4
6536 Berga, Germany

+49 341 600 37931

CO_2 HC NH_3

TLK-THERMO GMBH

www.tlk-thermo.de

Engineering / Contractor
Consultancy / Marketing
Training / Research

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

Hans-Sommer-Str. 5
38106 Braunschweig, Germany

+49 53 14 00 00 00

CO_2 HC NH_3

VAILLANT

www.vaillant.de

Manufacturer

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

Berghauser Strasse 40
42859 Remscheid, Germany

+49 21 91 18 27 54

HC

VULKAN LOKRING

www.vulkan-lokring.de

Manufacturer

Heating - Residential & Building
Refrigeration - Commercial / Industrial
Air Conditioning - Stationary / Mobile
Tube connections in the field of cooling/air Conditioning technology

Heerstraße 66,
44653 Herne, Germany

Postfach 20 04 68,
44634 Herne, Germany

+49 23 25 92 23 04

CO_2 HC

WIELAND-WERKE AG

www.wieland.de

Supplier

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

Graf-Arco-Str.36
89079 Ulm, Germany

+49 73 19 00 00 00

CO_2 HC NH_3

GREECE

AFOI MOUTEVELI LTD & CO EE
www.otenet.gr

Manufacturer
Engineering / Contractor

Refrigeration - Commercial
Refrigeration - Industrial

Andrianopoulou 16 & Prespas
18346 Moshato, Greece

+30 21 05 00 00 00

CO_2 HC NH_3

FRIGOGLASS
www.frigoglass.com

Manufacturer

Refrigeration - Commercial

15a Metaxa str.
14564 Kifissia, Athens, Greece

+30 210 61 65 400

CO_2 HC NH_3

HALCOR
www.halcor.gr/en/

Supplier

All
Copper Tubing

53 th km National Road
32011 Athens-Lamia, Greece

+30 226 20 53 158

CO_2 HC NH_3

KONTES SA
www.kontes.gr/sites/eng/

Manufacturer
Supplier
Refrigerant Repackager

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

12 Egaleo str.
18545 Piraeus, Greece

+30 21 05 00 00 00

CO_2 HC NH_3

HUNGARY

LHG KFT.
www.lhg.hu

Manufacturer
Engineering / Contractor

Refrigeration - Commercial
Refrigeration - Industrial

Alkotmány u. 86.
H-2800 Tatabánya, Hungary

+36 209 715 738

CO_2 HC NH_3

QPLAN KFT.
www.qplan.hu

Manufacturer
Supplier
Engineering / Contractor

Refrigeration - Commercial
Refrigeration - Industrial

Bécsi út 240/B.
H-1037 Budapest, Hungary

+36 30 92 53 087

CO_2 HC NH_3

IRELAND

ECOCUTE INNOVATION AND DESIGN LTD
www.ecocute.ie

Engineering / Contractor

Heating - Industrial & Commercial

5 Centre Point, Marina Commercial Park,
Centre Park Road
Cork, Ireland

+35 32 14 00 00 00

CO_2 HC NH_3

H&K INTERNATIONAL
www.hki.com

Manufacturer
Supplier
Engineering / Contractor

Refrigeration - Commercial

Knockmitten House,
Knockmitten Lane, Nangor Road,
Dublin 12, Ireland.

+35 3 1 60 55 400

CO_2 HC NH_3

INGERSOLL RAND THERMO KING
ingersollrand.com

Manufacturer
Supplier
Engineering / Contractor
Consultancy / Marketing

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

Rupprechtstr.10
DE-85399 Hallbergmoos, Ireland

+35 3 498 112 926

CO_2 HC NH_3

MRSLREF
www.mrslref.com

Engineering / Contractor

Refrigeration - Industrial

Park House, Park Road
Killarney Kerry, Ireland

+35 3 87 328 3511

CO_2 HC NH_3

MURCO
www.murco.ie

Manufacturer

Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Stationary

114a Georges Street Lower
Dun Laoghaire, Ireland

+35 3 12 84 63 88

CO_2 HC NH_3

RSL (IRL) LTD
www.rslireland.com

Supplier

Refrigeration - Commercial
Refrigeration - Industrial

Unit 46, Ballybane Ind. Est.
Galway, Ireland

+35 38 72 00 00 00

CO_2 HC NH_3

ITALY

BLUE FROST
www.bluebox.it

Manufacturer

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

via Valletta, 5
30010 Cantarana di Cona, Italy
+39 04 26 92 11 11

CO_2 HC NH_3

BLUPURA
www.blupura.com

Manufacturer

Refrigeration - Domestic
Refrigeration - Commercial

Via Aldo Moro SNC
60022 CASTELFIDARDO AN, Italy

+39 07 20 00 00 00

CO_2 HC NH_3

CAREL
www.carel.com

Supplier

Refrigeration - Commercial
Air Conditioning - Stationary

Via del Industria 11
35020 Brugine Padova, Italy
+39 04 99 71 66 11

CO_2 HC NH_3

CASTEL
www.castel.it

Supplier

Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Stationary

Via Provinciale, 2/4
20060 Pessano, Italy

+39 02 95 70 21

CO_2 HC NH_3

COSTAN SPA
www.costan.com

Manufacturer
Engineering / Contractor

Refrigeration - Commercial

Via Degli Alpini 14
32100 Limana,Italy

+39 04 38 00 00 00

CO_2 HC NH_3

DORIN
www.dorin.com

Supplier

Heating - Residential & Building
Refrigeration - Commercial
Refrigeration - Industrial

via aretina 388
50061 Compiobbi, Italy

+39 33 51 00 00 00

CO_2 HC NH_3

ELIWELL CONTROLS SRL
www.eliwell.it

Supplier
Engineering / Contractor

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

Via Dell'industria 15
32010 Pieve d'Alpago, Italy

+39 04 38 00 00 00

CO_2 HC NH_3

ENEX SRL
www.enex.it

Manufacturer

Heating - Industrial & Commercial
Refrigeration - Commercial
Refrigeration - Industrial

via Camalo 22
31050 Ponzano, Italy

+39 04 22 00 00 00

CO_2 HC NH_3

EPTA
www.eptarefrigeration.com

Manufacturer

Refrigeration - Commercial

Via Mecenate 86
20138 Milano, Italy

+39 02 55 40 32 11

CO_2 HC NH_3

FRASCOLD SPA

www.frascold.it

Supplier

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

V. Barbara Melzi 105
20146 Rescaldina (MI), Italy

+39 03 31 74 22 01

CO_2 HC NH_3

G.I. INDUSTRIAL HOLDING

www.gind.it

Manufacturer

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

Via Max Piccini 11/13
33050 Rivignano, Italy

+39 34 07 00 00 00

CO_2 HC NH_3

GALILEO TP

www.galileotp.com

Manufacturer
Supplier

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

Via del Pantano 73
50018 Scandicci, Italy

+39 055 722 17 31

CO_2 HC NH_3

GEOCLIMA

www.geoclima.com

Manufacturer
Engineering / Contractor

Refrigeration - Commercial
Air Conditioning - Stationary

Via dell' Industria, 12
34077 Ronchi dei Legionari (GO), Italy

+39 0481 774411

CO_2 HC NH_3

IARP

www.iarp.it

Manufacturer
Supplier

Refrigeration - Commercial

Via Achille Grandi 43 – Zona Industriale
15033 Casale Monferrato, Italy

+39 (0) 14 24 36 11

CO_2 HC NH_3

IGLU COLD SYSTEMS SRL

www.iglu.it

Manufacturer

Refrigeration - Commercial
Refrigeration - Industrial

Via Agnelli 6
33089 Villotta di Chions, Italy

+39 0434 630 840

CO_2 HC NH_3

INDESIT DEUTCHLAND

www.indesitcompany.com

Manufacturer

Refrigeration - Domestic

Viale Aristide Merloni, 47
60044 Fabriano (AN), Italia

+39 0732 66 11

CO_2 HC NH_3

IRD INIZIATIVE – REFRIGERA

www.refrigera.eu

Manufacturer

Refrigeration - Industrial

Via Chiavornicco 76
33084 Cordenons, Italy

+39 0434 54 22 66

CO_2 HC NH_3

LU-VE

www.luve.it

Supplier

Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Stationary

Via Caduti della Liberazione 53
21040 Uboldo, Italy

+39 02 96716 1

CO_2 HC NH_3

MAFLOW BRS
www.maflow.it

Supplier

Refrigeration - Transport
Air Conditioning - Mobile

Zona Ind.le Campolungo
63100 Ascoli Piceno, Italy

+39 07 36 00 00 00

CO_2 HC NH_3

OCS DI MAGGIOLO GIANCARLO
www.ocsmaggiolo.it

Manufacturer

Refrigeration - Industrial

Via Leonardo Da Vinci 18/20
35020 Brugine(PD), Italy

+39 049 973 01 84

CO_2 HC NH_3

RINNAI ITALIA
www.rinnai.it

Manufacturer

Heating - Residential & Building
Heating - Industrial and Commercial

Via Morbidina di Quartirolo 2B
41012 Carpi (MO), Italy

+39 059 6229248

CO_2 HC NH_3

RIVACOLD
www.rivacold.com

Manufacturer
Supplier

Refrigeration - Commercial
Refrigeration - Industrial

Via Sicilia 7
61020 montecchio, Italy

+39 0721 919911

CO_2 HC NH_3

ROBUR
www.robur.it

Manufacturer

Heating - Residential & Building
Air Conditioning - Stationary

Viale Parigi 4/6
24020 verdellino, Italy

+39 33 557 89 557

CO_2 HC NH_3

SCM FRIGO
www.scmfrigo.com

Manufacturer

Refrigeration - Commercial
Refrigeration - Industrial

Strada Zona Indutriale 10
35020 Vigoro Veadi Sant Angelo
Di Piove Di Sacco PD,Italy

+39 04 99 70 50 00

CO_2 HC NH_3

SCOTSMAN FRIMONT SPA
www.frimont.it

Manufacturer

Refrigeration - Commercial
Refrigeration - Industrial

Via Puccini 22
20010 Pogliano Milanese, Italy

+39 0294 00 00 00

CO_2 HC NH_3

SETTALA GAS SPA
www.settalagas.it

Manufacturer

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

via delle Industrie 18
20090 settala, Italy

+39 348 870 50 08

CO_2 HC NH_3

TEKLAB
www.teklab.biz

Manufacturer

Refrigeration - Commercial
Refrigeration - Industrial

via Emilia Ovest 1179
41123 Modena, Italy

+39 059 375 498

CO_2 HC NH_3

THERMOCOLD
www.thermocold.it

Manufacturer

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

Via dei Ciclamini 25
70026 Modugno, Italy

+39 080 531 26 23

CO_2 HC NH_3

WIGAM
www.wigam.it

Manufacturer
Supplier

Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Stationary
Air Conditioning - Mobile
Refrigerant recovery equipment + Detection systems + Refrigerant bottles

Wigam SpA Loc. Spedale 10/b
52018 Castel S. Niccolo, Rezzo, Italy

+39 0575 5011

CO_2 HC NH_3

LITHUANIA

JSC ROLVIKA
www.rolvika.lt

Manufacturer
Supplier

Engineering / Contractor
Heating - Industrial & Commercial
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Stationary

Kirtimu str.59
LT-02244 Vilnius, Lithuania

+37 052 602 088

CO_2 HC NH_3

LUXEMBOURG

COOL-TEC SA
www.cool-tec.lu

Supplier

Engineering / Contractor

Z.I. Rolach Hall 2
Luxembourg

+35 2 26 35 51 24

CO_2 HC NH_3

MACEDONIA

ENERGIJA DOO
www.energija.com.mk

Supplier

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

Londonska 1a
1000 Skopje, Macedonia

+389 2 3061 466

CO_2 HC NH_3

INFOSET LTD
ww.infoset.com.mk

Manufacturer
Supplier

Engineering / Contractor
Heating - Residential & Building / Industrial & Commercial
Refrigeration - Commercial / Industrial
Air Conditioning - Stationary

Serska 2b
1000 Skopje, Macedonia

+389 22 70 08 78

CO_2 HC NH_3

OZON DOOEL
baso@unet.com.mk

Manufacturer
Supplier

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

Zagrebska 45
1000 Skopje, Macedonia

+38 92 30 91 212

CO_2 HC NH_3

NETHERLANDS

COOL GREEN SOLUTIONS
www.coolgreensolutions.nl

Manufacturer

Heating - Industrial & Commercial
Refrigeration - Commercial
Refrigeration - Industrial

Postbus 369
4460 AT Goes, The Netherlands

+31 (0) 113 22 28 33

CO_2 HC NH_3

COLDSTOREDESIGN
www.coldstoredesign.com

Engineering / Contractor

Refrigeration - Industrial

P.O. Box 370
NL-8000 AJ Zwolle, Netherlands
+31 38 452 4858

CO_2 HC NH_3

FLAMCO
www.flamcogroup.com

Supplier

Heating - Industrial
Refrigeration - Industrial
Air Conditioning - Large Stationary

Amersfoortseweg 9
3751 LJ Bunschoten, The Netherlands

+31 (0) 33 299 75 00

CO_2 HC NH_3

INDUTHERM BV
www.indutherm.nl

Supplier

Heating - Industrial & Commercial
Refrigeration - Industrial

Vijzelweg 10
5144gh Waalwijk, Netherlands

+31 416 674 552

CO_2 HC NH_3

KWA BUSINESS CONSULTANTS
www.kwa.nl

Consultancy / Marketing
Training / Research

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

Regentesselaan 2
3818 HJ Amersfoort, The Netherlands

+31 33 42 21 330

CO_2 HC NH_3

NLR
www.nlr.nl

Research Institute
Thermal control systems for industry and space applicatons

Voorsterweg 31
8316PR Marknesse, Netherlands

+31 527 24 8628

CO_2 HC NH_3

P.W. VLASKAMP B.V. REFRIGERATION CONSULTANCY

www.vlaskamp.biz

Consultancy / Marketing

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

Albert Ruylweg 3
4254 EW Sleeuwijk, Netherlands

+31 18 33 10 848

CO_2 HC NH_3

SIMRAX BV

www.nl.ekk-eagle.com

Manufacturer
Engineering / Contractor

Compressor seals

Hopelerweg 250
6468 XX Kerkrade, The Netherlands

+31 45 54 69 209

CO_2 HC NH_3

UNIECHEMIE

www.uniechemie.nl

Supplier
Wholesaler

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

Aruba 21
7332BJ Apeldoorn, The Netherlands

+31 55 53 80 643

CO_2 HC NH_3

VAN KEMPEN KOUDETECHNIEK

www.vankempen-tiel.nl

Engineering / Contractor

Refrigeration - Industrial
Air Conditioning - Stationary

Spoorstraat 14
4001 CN Tiel, The Netherlands

+31 344 63 48 84

CO_2 HC NH_3

VHK

www.vhk.nl

consultancy / research for policies

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

Elektronicaweg 14
2628 XG Delft, The Netherlands

+31 15 27 55 755

CO_2 HC NH_3

WIJBENGA B.V.

www.wijbenga.nl

Manufacturer
Supplier
Engineering / Contractor

Refrigeration - Industrial

De Aaldor 12
4191PC Geldermalsen, The Netherlands

+31 345 681549

CO_2 HC NH_3

PENTAIR HAFFMANS

www.pentair.com

Manufacturer
Supplier

Engineering / Contractor
CO_2 Recovery incl. purification and liquefaction

Marinus Dammeweg 30
5928 PW Venlo, Netherlands

+31 77 32 32 300

CO_2 HC NH_3

NORWAY

BØRRESEN COOLTECH AS
www.borresen.no

Manufacturer
Supplier
Engineering / Contractor
Consultancy / Marketing

Training / Research
Heating - Industrial & Commercial
Refrigeration - Domestic
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Stationary

OSLO, Norway

+47 97 73 98 47

CO_2 HC NH_3

ELMO TEKNIKK AS
www.elmo.no

Engineering / Contractor

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

Gammelseterlia 12
6421 Molde, Norway

+47 97 64 13 91

CO_2 HC NH_3

HYDRO
www.hydro.com

Supplier

Air Conditioning - Mobile

Drammensveien 260
NO-0283 Oslo, Norway

+47 22 53 81 00

CO_2 HC NH_3

RENKULDE
http://renkulde.no

Supplier

All

Brobekkveien 90
0582 OSLO, Norway

+47 22 08 78 00

CO_2 HC NH_3

SINTEF
www.sintef.no

Training / Research

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

Stindveien 4
Trondheim, Norway

+47 73 59 30 00

CO_2 HC NH_3

SWECO NORGE AS
www.sweco.no

Consultancy / Marketing

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

Storetveitvegen 98
5072 Bergen, Norway

+47 99 15 03 87

CO_2 HC NH_3

THERMO CONSULT
www.thermoconsult.no

Supplier
Engineering / Contractor

Heating - Industrial & Commercial Heating - Industrial
Refrigeration - Commercial
Refrigeration - Industrial

Ilebergveien 3
N-3011 Drammen, Norway

+47 32 21 90 50

CO_2 HC NH_3

TRONDHEIM KULDE
www.trondheimkulde.no

Supplier
Engineering / Contractor

Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Large Stationary

Sorgenfri Road 18
7037 Trondheim, Norway

+47 73 83 26 80

CO_2 HC NH_3

VARMEPUMPEN AS

Engineering / Contractor

Heating - Residential & Building

Dagaliveien 14
1356 Bekkestua, Norway

+47 47 02 28 41

CO_2 HC NH_3

POLAND

KLIMA-THERM
www.klima-therm.pl

Supplier
Engineering / Contractor
Training / Research

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

ul. Tarnowiecka 54
04-174 Warszawa, Poland

+48 22 517 36 00

CO_2 HC NH_3

PPH COOL
www.cool.pl

Manufacturer
Engineering / Contractor

Heating - Industrial & Commercial
Refrigeration - Domestic
Refrigeration - Commercial
Refrigeration - Industrial

Lipowa 10
Chotomów, Poland

+48 662 129 833

CO_2 HC NH_3

ROMANIA

ABTECHNIC PROFESIONAL SRL
www.abtehnic.ro

Supplier
Engineering / Contractor
Consultancy / Marketing

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

Str. Alunisului 164
40747 Bucharest, Romania
+40 722 740 721

CO_2 HC NH_3

SC FRIGOTEHNICS SERV COM SRL
www.friginstall.ro

Supplier
Engineering / Contractor

Refrigeration - Commercial
Refrigeration - Industrial

Morarilor nr 1
2245 Bucharest, Romania

+40 72 35 66 747

CO_2 HC NH_3

SERBIA

AIR COOL

Engineering / Contractor

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

Dj.Andrejevica-Kuna 11
18000 Nis, Serbia

+381 18 575381

CO_2 HC NH_3

TERMES

Engineering / Contractor
Consultancy / Marketing

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

Zmaj Jovina 17/19
34000 Kragujevac, Serbia

+381 34 371 561

CO_2 HC NH_3

SPAIN

BEMA INDUSTRIAL

www.bema-exergetica.com

Engineering / Contractor

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

Villamanin, 37 3ºE
28011 Madrid, Spain

+34 91 52 61 733

CO_2 HC NH_3

COFRICO S.L.

www.cofrico.com

Installer

Heating - Industrial & Commercial
Refrigeration - Commercial
Refrigeration - Industrial

P.I. Bergondo, C/Parroquia de Guisamo B06
15165 Bergondo, A Coruña, Spain

+34 902 241 365

CO_2 HC NH_3

CUBIGEL COMPRESSORS

www.cubigel.com

Supplier

Refrigeration - Commercial

C/ Antoni Forrellad I Solá 2
08192 Sant Quirze del Vallès, Barcelona , Spain

+34 937 10 60 08

CO_2 HC NH_3

ELECTROAUTO, SA.

www.electroauto.net

Manufacturer
Engineering / Contractor

Training / Research
Air Conditioning - Mobile

Timanfaya, 39 6B
28924 ALCORCON, Spain

+91 66 90 475

CO_2 HC NH_3

FROST-TROL

www.frost-trol.com

Manufacturer

Refrigeration - Commercial

Ctra. Valencia-Barcelona, Km. 68,9, P.O Box 55
12004 Castellón, Spain

+34 964 34 27 40

CO_2 HC NH_3

KOXKA

Manufacturer

Refrigeration - Commercial

Polygon Landaben C / A s / n
31012 Pamplona, Spain

+34 948 18 81 00

CO_2 HC NH_3

TEWIS SYSTEMS
www.tewis.com

Manufacturer
Engineering / Contractor
Consultancy / Marketing

Training / Research
Refrigeration - Commercial
Refrigeration - Industrial

C/TRAGINERS Nº5
46014 Valencia, Spain

+34 96 31 34 049

CO_2 HC NH_3

UPV
www.upv.es

Training / Research

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

Camino de vera s/n
46022 Valencia, Spain

+34 96 28 79 120

CO_2 HC NH_3

VASEGRUPO ESPAÑA

Supplier
Engineering / Contractor
Consultancy / Marketing
Distribuitor

Heating - Industrial & Commercial
Refrigeration - Industrial

c/ Smara 9
33204 Gijon, Spain
+34 98 42 93 476

CO_2 HC NH_3

ZANOTTI IBERICA S.L.
www.zanotti.com

Manufacturer
Supplier

Refrigeration - Commercial / Industrial / Transport

C/K nave 15 I.E. El Oliveral
46394 Ribarroja del Turia (Valencia), Spain

+34 902 55 55 44

CO_2 HC NH_3

SWEDEN

ALFA LAVAL
www.alfalaval.com

Supplier

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

Rudebok Svagen 1
22655 Lund, Sweden

+46 46 36 65 00

CO_2 HC NH_3

CUPROBRAZE
www.cuprobraze.com

Association

Heating - Industrial & Commercial

c/o Advokatbyrån Broomé AB Stora Torget 6
SE72215 Västerås, Sweden

CO_2 HC NH_3

ENRAD AB
www.enrad.se

Manufacturer

Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Stationary

Olovsholmsgatan 32
50634 Boras, Sweden

+46 73 99 32 673

CO_2 HC NH_3

GREEN & COOL

www.greenandcool.com

Manufacturer
Training / Research

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

Ullebovägen 1
43253 Varberg, Sweden

+46 767 778 702

CO_2 HC NH_3

HAGLUND INDUSTRI

www.haglundindustri.se

Manufacturer
Supplier

Refrigeration - Commercial

sweden

+46 (0) 321 29 990

CO_2 HC NH_3

LUVATA

www.luvata.com

Consultancy / Marketing

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

61481 Söderköping, Sweden

+46 121 191 00

CO_2 HC NH_3

NIBE AB

www.nibe.se

Manufacturer

Heating - Residential & Building
Heating - Industrial & Commercial

Box 14
28521 Markaryd, Sweden

+46 705 709 489

CO_2 HC NH_3

RAMBÖLL SVERIGE AB

www.ramboll.se

Consultancy / Marketing

Refrigeration - Industrial

Box 17009
10462 Stockholm, Sweden

+46 106 156 000

CO_2 HC NH_3

SRS FRIGADON LTD

www.srs-comp.com

Manufacturer
Supplier

Refrigeration - Commercial
Air Conditioning - Stationary

Frigadon AB Box 7001
S-300 07 Halmstad, Sweden

+46 (0) 35 16 64 60

CO_2 HC NH_3

SWEP

www.swep.net

Manufacturer

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

Hjalmar Brantings väg 5, P.O. Box 105
26121 Lanskrona, Sweden

+46 418 40 04 00

CO_2 HC NH_3

TEMPER TECHNOLOGY AB

www.temper.se

Manufacturer
Supplier

Fluid supply

Exportgatan 49
422 46 Hisings Backa, Sweden

+46 (0) 31 748 04 05

CO_2 HC NH_3

TRANTER INTERNATIONAL AB

www.tranter.com

Supplier

Heating - Industrial
Refrigeration - Industrial
Air Conditioning - Stationary
Air Conditioning - Large Stationary

Box 1325
46228 Vänersborg, Sweden

+46 (0) 521 79 98 00

CO_2 HC NH_3

SWITZERLAND

A. SCHLEISS AG
www.schleissag.ch

Manufacturer
Supplier

Engineering / Contractor
Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Stationary

Breite 18
CH-4312 Magden, Switzerland

+41 61 841 23 13

CO_2 HC NH_3

ALPIQ
www.alpiq-energyservices.ch

Engineering / Contractor
Installer

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

route de Morrens 8
1053 Cugy, Switzerland

+41 21 731 92 93

CO_2 HC NH_3

FRIGO-CONSULTING AG
www.frigoconsulting.ch

Engineering / Contractor
Consultancy / Marketing
Training / Research

Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Stationary

Feldstrasse 30
3073 Guemligen, Switzerland

+41 (0)31 996 48 48

CO_2 HC NH_3

FRIOTHERM AG
www.friotherm.com

Manufacturer
Supplier

Engineering / Contractor
Heating - Industrial & Commercial

Zürcherstr. 12
8401 Winterthur, Switzerland

+41 (0) 52 / 2 62 80 80

CO_2 HC NH_3

GEORG FISCHER PIPING SYSTEMS AG
www.georgfischer.com

Manufacturer

Refrigeration - Commercial
Refrigeration - Industrial
Piping Systems

Ebnatstr. 111
CH8201 Schaffhausen, Switzerland

+41 (0) 52 / 631 3500

CO_2 HC NH_3

JÄGGI/GÜNTNER AG
www.jaeggi-hybrid.ch

Manufacturer
Supplier
Engineering / Contractor

Refrigeration - Industrial
Air Conditioning - Stationary

Hirschgässlein 11
4051 Basel, Switzerland

+41 (0) 61 560 9100

CO_2 HC NH_3

KIMESSA
www.kimessa.com

Supplier

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

Promenade de la Borgne 5
1967 Bramois, Switzerland

+41 (0) 22 756 00 00

CO_2 HC NH_3

PARKER HANNIFIN
www.parker.com

Supplier

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

Ch. Fbg de Cruseilles 16
1227 Carouge/Geneva, Switzerland

+41 22 30 77 247

CO_2 HC NH_3

PAULUS SCHWEIZ AG
www.paulusag.ch

Supplier
wholesaler

Refrigeration - Commercial
Air Conditioning - Stationary

Neuhofweg 50
4147 Aesch, Switzerland

CO_2 HC NH_3

SSP KÄLTEPLANER AG
www.kaelteplaner.ch

Engineering / Contractor
Consultancy / Marketing

Refrigeration - Domestic
Refrigeration - Commercial
Refrigeration - Industrial

Bittertenstrasse 15
4702 Oensingen, Switzerland

+41 62 388 03 50

CO_2 HC NH_3

WALTER WETTSTEIN AG
www.wwag.ch

Supplier
Engineering / Contractor

Training / Research
Heating - Industrial
Refrigeration - Industrial

Mattenstr. 11
3073 Gümlingen, Switzerland

+41 (0) 31 952 6262

CO_2 HC NH_3

TURKEY

FRITERM
www.friterm.com

Supplier

Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Stationary

Organize Deri San. Bölgesi 18. Yol Tuzla
34957 Istanbul, Turkey

+90 216 394 12 82

CO_2 HC NH_3

GOKCELER IC VE DIS TIC SOG SIS AS
www.refricomp.eu

Supplier

Refrigeration - Industrial

Cesmebasi Mh. Aksemsettin Cd. No:27
16335 Bursa, Turkey

+90 555 349 19 90

CO_2 HC NH_3

KALFA ENERJI SISTEMLERI VE INS SAN TIC LTD STI
www.kalfasan.com

Engineering / Contractor

Heating - Residential & Building

sait halim pasa cad no 31 Yeniköy
34464 Istanbul/Sariyer, Turkey

+90 53 37 00 00 00

CO_2 HC NH_3

KARYER
www.karyergroup.com

Supplier

Refrigeration - Commercial

Topcular Mah. Tikvesli Yolu No:8
34140 Topcular - Eyüp / Istanbul, Turkey

+90 212 567 55 09

CO_2 HC NH_3

PEPSICO BEVERAGES TURKEY
www.pepsico.com

Refrigeration - Commercial

Tekfen Tower Buyukdere Cad. No:209 4. Levent
34394 Istanbul, Turkey

+90 21 23 00 00 00

CO_2 HC NH_3

UKRAINE

PRIMEHOLOD
www.ukr.net

Engineering / Contractor

Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Stationary

Kharkovskiy,st., 3-A
2121 Kiev, Ukraine

+38 044 560-73-40

CO_2 HC NH_3

ДП "НИКОЛАЕВХОЛОД"

Engineering / Contractor

Heating - Residential & Building
Refrigeration - Domestic
Refrigeration - Industrial

ул.Електронная 81/8
54031 Николаев, Ukraine

+38 051 300 0000

CO_2 HC NH_3

UNITED KINDOM

AHT COOLING
www.ahtcooling.co.uk

Supplier

Refrigeration - Commercial

Top Angel, Buckingham Industrial Park
Buckingham MK18 1TH, UK

+44 (0) 1280 826 600

CO_2 HC NH_3

ARCTIC CIRCLE LTD
www.acl-online.com

Manufacturer
Training / Research

Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Stationary

Coldnose Court, Coldnose Rd
Rotherwas Industrial Estate
HR2 6JL Hereford, UK

+44 143 237 45 37

CO_2 HC NH_3

BJA REFRIGERATION CONSULTING ENGINEERS
www.bjacool.co.uk

Consultancy / Marketing

Refrigeration - Commercial
Refrigeration - Industrial

Bridge Mills
HD9 3TW Holmfirth, UK

CO_2 HC NH_3

BLIGHLINE LTD
www.blighline.co.uk

Manufacturer
Supplier

Refrigeration - Commercial

Lakesview business park
CT34JQ Canterbury, UK

+44 788 072 09 69

CO_2 HC NH_3

BOC
www.boc.com

Supplier

gas supply

priestley centre
gu27xy Guildford, UK

+44 788 150 07 58

CO_2 HC NH_3

CARTER RETAIL EQUIPMENT
www.cre-ltd.co.uk

Manufacturer
Supplier
Engineering / Contractor

Refrigeration - Commercial
Refrigeration - Industrial

Carter Coldstore Systems
Redhill Road, Hay Mills
B25 8EY Birmingham, UK

+44 (0) 121 250 1000

CO_2 HC NH_3

CARTER SYNERGY
www.cartersynergy.com

Supplier
Engineering / Contractor

Units 7&8, Heathrow
Causeway Estate, Ariel Way
TW4 6JW Hounslow, London, UK

+44 (0) 208 630 22 00

CO_2 HC NH_3

CCS REFRIGERATION LTD
www.ccsltd.net

Supplier
Engineering / Contractor
Consultancy / Marketing

Refrigeration - Commercial
Refrigeration - Industrial

The Barn, Middle Bleansley
LA20 6AR Cumbria, UK

+44 845 241 4955

CO_2 HC NH_3

CHEMVIRON CARBON
www.chemvironcarbon.com

Manufacturer

Supplier of activated carbons for gas storage and delivery

Edgar House, Lockett Road
WN4 8DE Ashton-in-Makerfield, UK

+44 (0) 1942 275 400

CO_2 HC NH_3

MILLBROOK HOUSE
www.dimplex.co.uk

Manufacturer
Supplier

Heating - Residential & Building
Heating - Industrial & Commercial

Millbrook House, Grange Drive, Hedge End,
SO30 2DF Southampton, Hants, United Kingdor

+44 (0) 845 600 5111

CO_2 HC NH_3

EARTHCARE PRODUCTS LTD
www.earthcareproducts.co.uk

Supplier

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

405 Mill Studio
SG12 9PY Ware, UK

+44(0) 84545 08480

CO_2 HC NH_3

ECO-FRIDGE UK LTD
www.eco-fridge.co.uk

Manufacturer

Refrigeration - Commercial

2 Wedgwood Road
OX26 4UL Bicester, UK

+44 (0) 1869 249965

CO_2 HC NH_3

F & T REFRIGERATION LTD
www.ftrefrigeration.co.uk

Engineering / Contractor

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

D C Griffiths Way
SA11 1BT Neath, UK

+44 (0) 1639 634171

CO_2 HC NH_3

FOSTER REFRIGERATION LTD.
www.fosterrefrigerator.co.uk

Manufacturer

Refrigeration - Commercial

Oldmedow Road, King's Lynn
PE30 4JU Norfolk, UK

+44 (0) 843 216 8800

CO_2 HC NH_3

GEORGE BARKER&CO.

www.georgebarker.co.uk

Manufacturer

Refrigeration - Commercial

Highfield Road
BD108RU Bradford,UK

+44 1274 703200

GR SCOTT LTD

www.grscott.co.uk

Manufacturer
Supplier
Engineering / Contractor
Consultancy / Marketing

Refrigeration - Commercial
Refrigeration - Industrial

Nova Scotia Works, Dale Street
Wf5 9HQ Ossett, UK

+44 (0) 1924 273537

HENRY TECHNOLOGIES

www.henrytech.co.uk

Supplier

Refrigeration - Commercial
Refrigeration - Industrial

Mossland Road, Hillington Park
G52 4XZ Glasgow, UK

+44 (0) 141 810 9181

HRP LTD

www.hrponline.co.uk

Supplier
Training / Research

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

Rougham Industrial Estate
IP30 9XA Bury St Edunds, UK

+44 1753 495 7000

HUSKY GROUP

www.huskyproducts.com

Manufacturer

Refrigeration - Commercial

Unit 8B Loughway Business Park
BT34 2TH Newry Co. Down, UK

+44 870 062 20 10

HYSAVE

www.hysave.co.uk

Manufacturer
Supplier
Engineering / Contractor
Training / Research
Refrigeration - Commercial

Refrigeration - Industrial
Refrigeration - Transport

Second Avenue
BA34BH Midsomer Norton,UK

+44 1761 416 123

I-A.C.SYSTEMS

www.ac-systems.com

Supplier

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

Bibury Close
SE15 6AE London, UK

+44 20 8133 3679

ICS HEATPUMP

www.icsheatpumps.co.uk

Supplier

Heating - Residential & Building
Heating - Industrial & Commercial

3 Trident Business Park, Amy Johnson Way
FY4 2RP Blackpool, UK

+44 (0) 8452 417 617

IDS

www.ids.com

Supplier

Refrigeration - Commercial
Refrigeration - Industrial

BS11 9HL Bristol, UK
+44 791 000 0000

INSTITUTE OF REFRIGERATION UK

ww.ior.org.uk

Association

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

Kelvin House, 76 Mill Lane
SM5 2JR Carshalton, UK

+44 (0) 208 647 7033

INTERLEVIN GROUP

www.interlevin.co.uk

Manufacturer

Refrigeration - Commercial

West Meadow Rise, Castle Donington
DE74 2HL Derby, UK

+44 (0) 1332 850090

MONTGOMERY REFRIGERATION

www.montgomery-ltd.co.uk

Supplier
Engineering / Contractor
Consultancy / Marketing

Refrigeration - Commercial
Refrigeration - Industrial
Air Conditioning - Stationary

5 Falcon Road Adelaide Industrial Estate
BT12 6RD Belfast, UK

+44 798 940 35 05

NH3 REFRIGERATION

www.nh3.co.uk

Supplier
Engineering / Contractor
Consultancy / Marketing

Refrigeration - Industrial

1 Minton Enterprise Park
CB8 7YY Newmarket, UK

+44 788 414 82 44

RD&T

www.rdandt.co.uk

Training / Research

Refrigeration - Domestic
Refrigeration - Commercial

Churchill Building
BS405DU Langford, UK

+44 117 900 0000

RDA (ENVIRONMENTAL ENGINEERING LIMITED)

www.rda-eng.com

Manufacturer
Supplier

Refrigerant recovery equipment

Riverway Industrial Estate
PO30 5UX Newport, Isle of Wight, UK

+44 (0) 1983 821189

RE-PHRIDGE

www.re-phridge.co.uk

Engineering / Contractor
Consultancy / Marketing
Training / Research

Refrigerants

PO Box 4745
CV37 1FE Stratford-upon-Avon, UK

RESOURCE DATA MANAGEMENT

www.resourcedm.com

Supplier

Refrigeration - Commercial
Refrigeration - Industrial

80 Johnstone Avenue
G52 4NZ Glasgow, UK

+44 (0) 141 810 2828

SEWARD REFRIGERATION

www.sewardrefrigeration.com

Supplier
Engineering / Contractor

Refrigeration - Industrial

Unit 8, Platinum Road,
Off Cobalt Avenue, Urmston
M41 7LJ Manchester, UK

+44 (0) 161 724 0357

SHRIEVE PRODUCTS INTERNATIONAL
www.shrieve.co.uk

Supplier

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

Suite 21, 70 Churchill Square
ME19 4YU West Malling, UK

+44 173 300 0000

CO_2 HC NH_3

SPACE ENGINEERING SERVICES
www.space-engineering.co.uk

Manufacturer
Engineering / Contractor

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

Causeway Central, Pioneer Park
BS4 3QB Bristol, UK

+44 0845 602 0670

CO_2 HC NH_3

STAR REFRIGERATION
www.star-ref.co.uk

Manufacturer
Engineering / Contractor
Consultancy / Marketing
Training / Research

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

Thornliebank Ind est
G46 8JW Glasgow, UK

+44 141 638 7916

CO_2 HC NH_3

TITAN ENGINEERING LTD.
www.titanengineering.co.uk

Supplier
Engineering / Contractor

Refrigeration - Industrial
Air Conditioning - Stationary
Air Conditioning - Large Stationary

Cornwall House
Station Approach Princes Risborough
HP27 9DN Buckinghamshire, UK

+44 (0) 1844 / 342 581

CO_2 HC NH_3

TRUE MANUFACTURING
www.truemfg.com

Manufacturer
Supplier
Engineering / Contractor

Refrigeration - Commercial

Field's End Road, Goldthorpe, Nr.Rotherham
S639EU SouthYorkshire, UK

+44 (0) 1709888080

CO_2 HC NH_3

VERCO LIMITED
www.ver.co.uk

Manufacturer
Supplier

Refrigeration - Commercial

Hithercroft Road
Wallingford
OX10 9DG Oxfordshire, UK

+44 (0) 1491 839966

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WIKA INSTRUMENTATION LTD
www.wika.co.uk

Manufacturer

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

4 Gatton Park Business Centre
RH1 3LG Mershtham Redhill, UK

+44 787 040 19 47

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WILLIAMS REFRIGERATION
www.williams-refrigeration.com

Manufacturer
Supplier
Engineering / Contractor

Refrigeration - Commercial
Charging and evacuation stations

Bryggen Road, North Lynn Indust., Est.
PE30 2HZ King's Lynn, UK

+44 (0) 1553 817 000

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SANYO ELECTRIC CO., LTD.
http://eu.sanyo.com

Manufacturer

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

18 Colonial Way
370-0532 Watford, Herts,WD24 4PT, UK

+44 (0) 1923 246363

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THE PULSE SUPPORTERS (HELPED TO DISSEMINATE SURVEY)

EUROPE

AREA (Air Conditioning & Refrigeration European Association)
area.autodesk.com

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Association

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

Bd. A. Reyers 80
1040 Brussels, Belgium

+32 2 706 82 37

EHPA (European Heat Pump Association)
www.ehpa.org

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Association

Renewable Energy House
Rue d'Arlon 63-67
B-1040 Brussels, Belgium

+32 24 00 10 17

REHVA (Federation of European Heating, Ventilation & Air Conditioning Associations)
www.rehva.eu

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Association

40 Rue Washington
1050 Brussels, Belgium

+32 2 51 41 17

UNITED KINGDOM

BRA (British Refrigeration Association)
www.feta.co.uk

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Association

Federation of Environmental Trade Associations Ltd
2 Waltham Court, Milley Lane
Hare Hatch, Reading
RG10 9TH Berkshire, UK

+ 44 (0)118 940 3416

HVAC&R ASSOCIATIONS & RESEARCH INSTITUTES

USED AS SOURCES, REPLIED TO SURVEY, PROVIDED INFORMATION FOR THE "GUIDE"

INTERNATIONAL

IIR (International Institute of Refrigeration)
www.iifiir.org

Training / Research
Association

177, boulevard Malesherbes
75017 Paris, France
International

+33 1 42 27 32 35

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IIAR (International Institute of Ammonia Refrigeration)
www.iiar.org

Association

1001 N. Fairfax Street, Suite 503
VA 22314 Alexandria, US

+1 703 312 4200

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EUROPE

EURAMMON
www.eurammon.com

Association

Lyoner Strasse 18
60528 Frankfurt,Germany

+49 (0)69 6603 1277

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ECSLA (European Cold Storage and Logistics)
www.ecsla.be

Association

Refrigeration - Commercial
Refrigeration - Industrial
Refrigeration - Transport

4, rue Jacques de Lalaing
1040 Brussels, Belgium

+32 2 514 56 60

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BELGIUM

KHLIM
www.khlim.be

Training / Research

Refrigeration - Commercial

Centrum Zuid 2413/40C
3530 Houthalen, Belgium

+32 47 89 04 165

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DENMARK

AUTHORIZED REFRIGERATION VINSTALLERS ASSOCIATION (AKB)
www.koeleteknik.dk

Association

Vestergade, 28 - Postboks 323
4000 Roskilde, Denmark

+45 46 32 21 11

CO_2 HC NH_3

KVCA (Køle VirksomhedsCenter, Alsion-DK)
www.kvca.dk

Association

Refrigeration - Domestic / Commercial
Refrigeration - Industrial / Transport
Air Conditioning - Stationary / Large Stationary

Alsion 2
6400 Sønderborg, Denmark

+45 6550 8090

CO_2 HC NH_3

FRANCE

CEMAFROID
www.cemafroid.fr

Training / Research

Parc de Tourvoie, BP 134,
92185 Antony cedex, France

+33 1 40 96 65 06

CO_2 HC NH_3

AFF (Association Française du Froid)
www.aff.asso.fr

Association

Refrigeration - Industrial

2 impasse des mésanges
1350 Culoz, France

+33 4 79 42 62 68

CO_2 HC NH_3

CNAM
www.cnam.fr

Training / Research

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

France

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GERMANY

KARLSRUHE UNIVERSITY OF APPLIED SCIENCE
www.hs-karlsruhe.de

Training / Research

Moltkestrasse 30
76133 Karlsruhe, Germany

+49 721 925 1843

CO_2 HC NH_3

GIZ
www.giz.de

Not-for-profit organisation

Friedrich-Ebert-Allee 40
53113 Bonn, Germany

+49 228 44 60-0

CO_2 HC NH_3

ITALY

ASSOCIAZIONE DEI TECNICI DEL FREDDO

www.associazioneatf.org

Training / Research
Association

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

Via Alessandria 26
15033 Casale Monferrato, Italy

+39 014 20 00 000

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DEF - UNIVERSITY OF FLORENCE

www.vega.de.unifi.it

Training / Research

CO2 cycles

via S. Marta, 3
50139 Firenze, Italy

CO_2 HC NH_3

ENEA

www.enea.it

Training / Research

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

Via Anguillarese,301
123 Roma Italy

+39 063 000 00 00

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NETHERLANDS

EINDHOVEN CENTER FOR SUSTAINABILIT ECFS

Training / Research

Technical University, Connector 1.15b
Het Eeuwsel 6, P.O. Box 513
5600 Eindhoven, Netherlands

+31 40 247 4463

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NVKL (Nederlandse Vereniging van Ondernemingen op het gebied van de Koudetechniek en Luchtbehandeling)

www.nvkl.nl

Association

Boerhaavelaan, 40 - Postbus 190,
2700 AD Zoetermeer, Netherlands

+31 88 400 84 90

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RE/GENT

www.re-gent.nl

Training / Research

Lagedijk 22
5705BZ Helmond, Netherlands

+31 492 476365

CO_2 HC NH_3

NORWAY

VKE (Foreningen for Ventilasjon Kulde og Energi - Norwegian Refrigeration and HVAC Association)

Association

Box 5467 Majorstuen
0305 OSLO, Norway
+47 23 08 77 01

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PORTUGAL

TECSISEL, LDA
www.tecsisel.pt

Training / Research

Industrial and building automation
Edificio Tecsisel
Rua das Queimadas, Nº6 - Sernada
3505-330 Viseu, Portugal

+351 23 20 00 000

CO_2 HC NH_3

SPAIN

THERMAL ENGINEERING GROUP JAUME I UNIVERSITY
www.uji.es

Training / Research

Refrigeration - Commercial
Refrigeration - Industrial

Campus Riu Sec
E12071 Castellón de la Plana, Spain

+34 964728136

CO_2 HC NH_3

SWEDEN

SP TECHNICAL RESEARCH INSTITUTE OF SWEDEN
www.sp.se

Training / Research

SP Technical Research Institute of Sweden
50115 Boras, Sweden

+46 10 516 5544

CO_2 HC NH_3

AMMONIA PARTNERSHIP AB
www.ammoniapartnership.se

Training / Research

Refrigeration - Commercial
Refrigeration - Industrial

Nyponv. 24
263 62 Viken, Sweden

+46 42 238155

CO_2 HC NH_3

SWITZERLAND

HSR FACHHOCHSCHULE RAPPERSWIL
www.hsr.ch

Training / Research

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

Oberseestr. 10
8640 Rapperswil, Switzerland

+41 55 222 4333

CO_2 HC NH_3

UNITED KINGDOM

TECHTRAIN ASSOCIATES LTD
www.techtrain.co.uk

Training / Research

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

Unit C4, Beighton Link Business Park
Old Colliery Way
S20 5NL Sheffield, UK

+44 (0) 114 2871930

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Keep it clean. Protect the environment with Danfoss natural refrigerants solutions

The industry is moving towards low GWP refrigerants.For many years, Danfoss has been developing solutions for natural refrigerants (low GWP). Danfoss has a broad product range for NH_3, HC and CO_2 refrigerant applications and is continuously developing new components suitable for natural refrigerants.

www.danfoss.com/co2

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 at global energy supplier Norsk Hydro, for the last 5 years she has 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.

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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.

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Alexandra pursued post-graduate studies in Environmental and Resource Economics at University College London, UK. Environmental issues have hereinafter 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 supports the company's public affairs department in making policy makers aware of the benefits of climate friendly natural refrigerant-based technologies.

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