



**COOL TECHNOLOGIES:
WORKING WITHOUT HFCs**

Examples of HFC-Free Cooling Technologies in Various Industrial Sectors¹

2012 EDITION

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¹ Greenpeace published a report under the same title in 2000, 2008, 2009 and 2010; and it continues to be updated. Greenpeace welcomes receiving information regarding new examples of HFC-free technologies. Please forward them to jmate@telus.net

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Greenpeace Disclaimer

The “COOL TECHNOLOGIES: WORKING WITHOUT HFCs” Report presents a sample survey of companies using HFC-free technologies. The survey is not meant to be all-inclusive, nor is the inclusion of any enterprise an endorsement by Greenpeace of any company or its products.

Contact Information

Greenpeace routinely updates the “Cool Technologies: Working Without HFCs” Report and welcomes additional information.

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A. INTRODUCTION

Just as there was no single “magic bullet” to replace CFCs, there is no single solution to replace HCFCs. However, there is a wide variety of environmentally superior and technologically proven HCFC and HFC-free alternatives to meet our cooling needs. These alternatives include natural refrigerants (CO₂, hydrocarbons, ammonia, water, etc.), secondary cooling systems, desiccant cooling, evaporative cooling, absorption cooling, and innovative building designs that can eliminate the need for mechanical cooling. Natural refrigerants and foaming agents, in contrast to fluorocarbons, abundantly occur in the biosphere, they maintain a steady state, and are easily absorbed by nature.

HFC-free technologies exist in nearly the full spectrum of applications, such as:

- Domestic Refrigeration and Air-Conditioning
- Commercial Refrigeration and Air-Conditioning
- Mobile Air-Conditioning
- Industrial Processes
- Insulation Foam Blowing

Furthermore, new HFC-free products are entering the market almost on a weekly basis. There is a domino effect in cooling technologies. When one company achieves a breakthrough others soon replicate. Technological innovations in one sector soon impact on innovations in other sectors.

At the present time, technologies with natural substances are primarily used in industrialized countries, but there is no reason why they cannot be used worldwide. Of course, as with all refrigerants, best safety practices must be followed when working with natural refrigerants (see section D.9.a)

Developing countries would greatly benefit by leapfrogging HFCs altogether, and going straight from HCFCs to long-term solutions that rely on natural refrigerants and foam blowing agents, thus avoiding reliance on more expensive, less efficient HFCs that will need to be phased out because of their significant contributions to global warming. Furthermore, they could finally escape the clutches of the fluorocarbon chemical industry’s monopoly over their choice of technology.

The following sampling of companies and enterprises using HFC-free technologies is provided to demonstrate that there is already a wide array of safe and commercially proven HFC-free technologies available to meet nearly all those human needs that were formerly met by fluorocarbons.²

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B. Domestic Refrigeration

B.1 GreenFreeze: hydrocarbon domestic refrigeration

There are over 650 million hydrocarbon, or GreenFreeze, refrigerators in the world today. The GreenFreeze technology was developed by Greenpeace in 1992. The organization made the technology freely available to the world. The term GreenFreeze refers to refrigerators and freezers that contain no fluorocarbons. Typically, they use cyclopentane for the foam and isobutane (R-600a) as the refrigerant. The refrigerant charge of 30 to 100 grams varies according to the size and special features of the refrigerator. GreenFreeze refrigerators are available in all sizes, with typical standard and luxury features, including automatic defrost systems.

100 million domestic refrigerators and freezers are produced in the world each year, and GreenFreeze technology represents between 35% and 40% of the total. It is projected that at least 75 to 80% of global new refrigerator production will use hydrocarbon refrigerants by 2020³.

All of the major European, Japanese, and Chinese manufacturers now produce GreenFreeze refrigerators, with the technology now dominating these markets. In China alone, 75% of new domestic refrigerators use R-600a.⁴ It is also produced in South America with countries such as Argentina and Brazil in the forefront. In 2010, Brazilian power companies initiated a refrigerator exchange program, replacing older fluorocarbon models with new hydrocarbon based refrigerators.⁵

GreenFreeze entered the Mexican market in 2009. In 2011 the US Environmental Protection Agency approved the use of hydrocarbons in domestic refrigeration in the United States under the Significant New alternatives Policy (SNAP) program. In 2012 GE introduced the first hydrocarbon refrigerator into the US market.⁶

Table 1: Partial list of companies producing GreenFreeze domestic refrigerators

Company	Country	Notes
AEG	Germany	
Arcelik	Turkey	
Autosal	Argentina	Produces the Columbia and Koh-i-noor brands in Argentina.
AUX	China	
Bauknecht	Germany	
Bosch	Germany	
Bosch	Brazil	
Bosch Siemens Hausgerate BSH Russia	Russia	
Bosch Siemens Hausgerate BSH Mexico	Mexico	Began marketing in March 2009, in cooperation with retailer Sears Mexico. First penetration of hydrocarbon technology into a North American market.
Brastemp	Brazil	
Candy Group	Italy	
Columbia	Argentina	Brand
Continental	Brazil	Brand
Electrolux	Sweden	
Electrolux	Hungary	
Electrolux	Australia	
Email	Australia	
Fisher & Paykel	New Zealand	
Frestech	China	
General Electric	USA	In 2012, GE introduced the first hydrocarbon refrigerator into the US market, under the brand name Monogram. Monogram is a 30 inch-wide high-end refrigerator.
General Electric	Brazil	
Godrej	India	
Gorenje	Germany	
Gram	Denmark	
Haier	China	
Hartono Istana Electronics	Indonesia	
Hindustan Refrigerator	India	

³ UNEP Technology and Economic Assessment Panel 2010 Progress Report: "Assessment of HCFCs and Environmentally Sound Alternatives," p.37

⁴ UNEP Report of the Technology and Economic Assessment Panel, 2010 Progress Report

⁵ <http://oz-chill.com/refrigerator-exchange-programme-in-brazil-f-gas-out-natural-refrigerant-in/>

⁶ <http://pressroom.geconsumerproducts.com/pr/ge/entertaining-dream-ge-30-monogram-230137.aspx?ncid=23853>

Table 1, cont'd

Company	Country	Notes
Hitachi	Japan	
Husky Deutschland	Germany	
Indesit Deutschland	Germany	
Inpud	Cuba	
Kelon	China	
Koh-I-Noor	Argentina	Brand
Konka	China	
LG Electronics Inc.	South Korea	
Liebherr	Germany	
Matsushita	Japan	
Meiling	China	
Miele	Germany	
Panasonic	Japan	
Palfridge (The Fridge Factory)	Swaziland	Palfridge, with the support of GIZ ProKlima, the Multilateral Fund of the Montreal Protocol and UNDP is the first factory in Africa to have converted its entire production line to hydrocarbons. The company also developed its own prototype of SolarChill.
Quelle	Germany	
Samsung	China	
Sanyo	Japan	
Sharp	Japan	
Siemens Home	Germany	
Thompson	France	
Toshiba	Japan	
Vestfrost	Denmark	Vestfrost also produces SolarChill vaccine coolers.
Voltas	India	
Whirlpool	Italy	
Whirlpool	Argentina	
Zanussi Electrolux	Italy	

B.2 SolarChill⁷: hydrocarbon vaccine cooler and refrigerator

SolarChill is a breakthrough technology in vaccine cooling and domestic and small commercial refrigeration. Twelve years in the making, the SolarChill technology is relatively simple. Solar power from two or three 60 watt or 80 watt solar panels run a direct current compressor. The compressor runs the refrigerant cycle which in turn produces an ice bank that maintains the required temperature in the cabinet. The power of the sun is essentially stored in an “ice battery”. It is basically a contemporary solar version of the old fashioned ice box.

A thermostat maintains the units at the required temperatures. The required temperature range for vaccines is between 2 and 8 °C, day and night. The optimum temperature range for perishable food storage is 3 to 5 °C. In low-sun situations, or with power completely disrupted, the thick insulation of the cabinet maintains acceptable temperatures for up to 5 days. The recommended ambient temperatures varies according to models. In field tests, units have operated under a wide range of ambient temperatures; from +10°C to +42°C. New models are underway for 48°C ambient temperatures.

There are two models of SolarChill: SolarChill A, a 50 liter unit for vaccine cooling and SolarChill B, a 100 liter unit for food refrigeration. SolarChill B is for domestic and light commercial use. Both models operate under the same principles. There are plans for developing larger SolarChill models.

While SolarChill A is primarily for use in off-grid regions of developing countries, SolarChill B has market potential in off-grid regions of all countries (e.g. recreational cottages). The vaccine cooler model is already commercialized while the food refrigerator model is still in the R&D phase.

⁷ The SolarChill Project partner organizations are the Danish Technological Institute (DTI), the German Government Development Agency (GIZ ProKlima), Greenpeace International, Program for Appropriate Technology in Health (PATH), United Nations Environment Programme (UNEP), United Nations Children's Fund (UNICEF), World Health Organization (WHO), and the World Bank. SolarChill Industry Participants include Vestfrost and Danfoss. Please see www.solarchill.org “Contacts” for the names and contact information of individual representatives.

Table 2: SolarChill technology vaccine coolers and food refrigerators

Company	Model Type	WHO PQS Prequalification	Notes
Vestfrost (Denmark)	MKSO44 Vaccine cooler	Yes	Prequalified for +20°C to +32° C ambient temperatures (but have operated under a wider range of ambient temperatures; from +10°C to +42°C). Fan controlled by a rechargeable ancillary battery. Gross volume: 48 liters Storage capacity: 19.5 liters Autonomy time: 147 hours Holdover time: 114 hours Cool down time: 96 hours Power requirement: 160 watts Approximate cost without solar panels: 1100 EUR Commercialized
Haier (China)	HBC-60 Vaccine Cooler	Yes	Prequalified for 43° C Gross volume: 50 liters Storage capacity: 21litres Autonomy time: 72 hours Holdover time: 25 hours Power requirement: 180 watts Approximate cost without solar panels: 1,066 EUR
True Energy (UK)	BLF 100 DC Vaccine Cooler	Yes	Prequalified for +5° to 43° C Gross volume: 99 liters Storage capacity: 124 liters Autonomy time: 72 hours Holdover time: 170 hours Cool down time: 148 hours Approximate cost without solar panels: 3,050 EUR
Palfridge (Swaziland)	MC72 - Medical Unit	PQS application pending	Designed for 48° C ambient temperatures Gross volume: 50 liters Storage capacity: 20 liters Approximate cost with solar panels: 1400 EUR
Palfridge (Swaziland)	LS150- Domestic	N/A	Food storage Single door design Separate fridge and freezer compartment Maintains temperatures from +2° to 9° C Approximate cost with solar panels: 1350 EUR

C. COMMERCIAL AND INDUSTRIAL REFRIGERATION

C.1 Natural refrigerants in commercial cooling equipment

Today, commercial refrigeration represents 40% of total annual refrigerant emissions, and it is expected to represent 47% by 2015.⁸ It is the refrigeration subsector with the largest CFC, HCFC, and HFC CO₂-equivalent refrigerant emissions.⁹ There are three main types of commercial and industrial refrigeration equipment: (a) stand alone plug-in equipment, (b) condensing units, (c) centralized systems. Equipment using natural refrigerants is available for each of these applications.

C.1.a Refrigerants, Naturally!

Refrigerants, Naturally! is a global initiative of multinational corporations that aims to replace the use of HCFCs and HFCs in their point-of-sale cooling applications. Refrigerants, Naturally! supports a positive regulatory and political framework for investment in climate-friendly technologies. Current partners include Coca-Cola, Unilever, McDonald's, PepsiCo and Red Bull. The initiative is supported by Greenpeace and the United Nations Environment Program (UNEP). In 2011, Refrigerants, Naturally! received the Roy Family Award for Environmental Partnership of Harvard University's John F. Kennedy School of Government.

Table 3: Use of natural refrigerants in point-of-sale cooling equipment by member companies of Refrigerants, Naturally!

Company	Application	Notes
Coca-Cola	Food and beverage	<p>Since 2000, Coca-Cola has developed new, high-efficiency, CO₂ technology for commercial equipment (vending machines, coolers and fountain dispensers). On December 3, 2009, Coca-Cola announced that, globally, 100% of their new vending machines and coolers will be hydrofluorocarbon-free (HFC-free) by 2015.¹⁰ To date (April 2012), Coca-Cola has placed 600,000 units using natural refrigerants worldwide.</p> <p>Coca Cola Enterprises, the exclusive Coca-Cola bottler for all of Belgium, continental France, Great Britain, Luxembourg, Monaco, The Netherlands, Norway and Sweden, plans to only purchase HFC-free coolers as of January, 2013.¹¹</p> <p>According to Coca-Cola, under 'D' conditions, that is 40°C ambient temperatures, key suppliers achieved better efficiency with CO₂ than with HFC-134a, and in all countries in the world, yearly averages indicate that CO₂ in beverage cold drink equipment performs better than R134a.</p>
PepsiCo	Food and beverage	<p>To date (April 2012), Pepsi has over 147,000 HFC-free units (coolers and vending machines) in the field worldwide. The majority of these units are hydrocarbon-based. The company has pioneered the testing of CO₂ and hydrocarbon equipment in the United States. Since 2009, all of Pepsi's commercial cooling equipment in Turkey has been HFC-free.</p> <p>The new hydrocarbon units contain R290 (propane) and R600a (isobutane) refrigerants that cut direct greenhouse gas emissions by 99%. In terms of energy efficiency, the new units use on average 48% less energy than the 2004 models. In pilot projects in the United States the hydrocarbon units used 20% less energy than the Energy Star requirements.¹²</p>
Red Bull	Food and beverage	<p>Red Bull has started the switch to ECO-Coolers for the cooling of beverages in recent years. ECO-Coolers combine the use of hydrocarbons (R290 and R600a) and cooler technical improvements, such as energy efficient fans. ECO-Coolers consume up to 45% less energy than previous generations of cooling equipment. Red Bull is monitoring the performance of its ECO-Coolers in various countries. Based on favorable CO₂ emissions data, Red Bull's ordering guidelines guarantee that wherever feasible, from a legal and technical point of view, only ECO-Coolers will be installed in the future. As of 2012, there were 313,000 ECO-Coolers in use worldwide, representing 35% of Red Bull's entire fleet of cooling equipment.¹³</p>

⁸ SROC Report : IPCC Special report for UNFCCC and Montreal Protocol

⁹ IPCC/TEAP, 2005 as reported in TemaNord. 2007: "Potent Greenhouse Gases: Ways of Reducing Consumption and Emission of HFCs, PFCs 7 SF6": report prepared for the Nordic Council of Ministers p. 32

¹⁰ www.thecoca-colacompany.com/sustainabilityreport/TCCC_2010_2011_Sustainability_Report_Full.pdf

¹¹ <http://www.r744.com/news/view/3170>

¹² Communication between PepsiCo and Greenpeace, April 2012.

¹³ Communication between Red Bull and Greenpeace, April 2012.

Table 3, cont'd

Company	Country	Notes																																	
McDonald's	Food and beverage	In 2003, McDonald's opened the world's first HFC- and HCFC-free restaurant in Vejla, Denmark. This pilot project realized CO ₂ emission reduction of approximately 27% to a comparable control McDonald's restaurant. ¹⁴ The test equipment included:																																	
		<table border="1"> <thead> <tr> <th>Equipment</th> <th>Current refrigerant</th> <th>Alternative refrigerant</th> </tr> </thead> <tbody> <tr> <td>Soda Machine (post-mix type)</td> <td>HFC-404a</td> <td>R290 (propane)</td> </tr> <tr> <td>Juice Dispenser</td> <td>HFC-404a</td> <td>R290 (propane)</td> </tr> <tr> <td>Milkshake and Ice Cream Machine</td> <td>HFC-404a</td> <td>R290 (propane)</td> </tr> <tr> <td>Meat Freezer</td> <td>HFC-404a</td> <td>R290 (propane)</td> </tr> <tr> <td>Wall-Hung Freezer</td> <td>HFC-404a</td> <td>R290 (propane)</td> </tr> <tr> <td>Ice Cube Machine</td> <td>HFC-404a</td> <td>R290 (propane)</td> </tr> <tr> <td>Salad Refrigerator</td> <td>HFC-134a</td> <td>R600a (isobutane)</td> </tr> <tr> <td>Refrigerating Room</td> <td>HFC-134a</td> <td>R290 and CO₂</td> </tr> <tr> <td>Freezing Room</td> <td>HFC-404a</td> <td>R290 and CO₂</td> </tr> <tr> <td>Air-Conditioning and Heating</td> <td>HFC-407c</td> <td>CO₂</td> </tr> </tbody> </table>	Equipment	Current refrigerant	Alternative refrigerant	Soda Machine (post-mix type)	HFC-404a	R290 (propane)	Juice Dispenser	HFC-404a	R290 (propane)	Milkshake and Ice Cream Machine	HFC-404a	R290 (propane)	Meat Freezer	HFC-404a	R290 (propane)	Wall-Hung Freezer	HFC-404a	R290 (propane)	Ice Cube Machine	HFC-404a	R290 (propane)	Salad Refrigerator	HFC-134a	R600a (isobutane)	Refrigerating Room	HFC-134a	R290 and CO ₂	Freezing Room	HFC-404a	R290 and CO ₂	Air-Conditioning and Heating	HFC-407c	CO ₂
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		Freezing Room	HFC-404a	R290 and CO ₂																															
Air-Conditioning and Heating	HFC-407c	CO ₂																																	
In 2011, McDonald's Germany opened the first HFC-free restaurant in Heidelberg. To date, McDonalds Europe, in partnership with their equipment suppliers have developed and approved HFC-free alternatives for six of the eight pieces of refrigeration equipment: juice dispensers, ice cube machines, frozen fry dispensers, drinks systems, reach-in coolers and freezers and meat/wall freezers. McDonald's Europe has already implemented 1495 HFC-free meat freezers, 845 frozen fry dispensers and 1025 reach-ins and salad displays and are continuing to work with suppliers to push for viable alternatives for all refrigerant equipment. The company plans to have in place HFC-free solutions for all small refrigeration systems by the end of 2013 and start development of HFC-free solutions for the remaining larger systems. ¹⁵																																			
Unilever	Food and beverage	By January 2012, Unilever had placed over 900,000 hydrocarbon ice cream freezers around the world, including South Africa, China, Europe, Brazil, and a trial in the United States. These freezers contain less than 150g of hydrocarbons in their refrigerating circuit, and have a 9% energy savings over their HFC counterparts. ¹⁶ The company will reach the 1-million unit mark by the end of 2012, and by 2015 all of Unilever's new ice cream freezers will be HFC-free. In an industry precedent setting move, Unilever pioneered the testing of hydrocarbon ice cream freezers in the United States in its Ben & Jerry's ice cream stores. In 2008, the company requested from the EPA to test up to 2,000 units. With this move, Unilever penetrated the wall of regulatory obstacles that had, until then, kept hydrocarbon cooling technologies out of North America. Unilever was the instrumental in influencing the EPA's subsequent approval of hydrocarbons in 2011. In 2012, the company announced plans to roll-out hydrocarbon freezer cabinets in the US for other Unilever brands (including Breyers, Good Humor, Klondike, Magnum and Popsickle). ¹⁷																																	

¹⁴ UNEP DTIE OzonAction : HCFC Help Centre : www.unep.fr/ozonaction/topics/hcfc_case-studies.htm : McDonalds' : world's first HFC-free restaurant.

¹⁵ Communication between McDonald's and Greenpeace, April 2012.

¹⁶ <http://www.unilever.com/ourvalues/environment-society/case-studies/climate-change/hydrocarbon-ice-cream-cabinets.asp>

¹⁷ <http://www.hydrocarbons21.com/content/articles/125220120215.php>

C.1.b The Consumer Goods Forum

The Consumer Goods Forum (CGF) is a body comprising of over 650 retailers, manufacturers, service providers and other stakeholders from 70 countries, with a combined turnover of \$2.8 trillion. In November 2010, spurred on by member companies of Refrigerants, Naturally!, the CGF pledged to begin phasing-out HFCs as of 2015 and replace them with non-HFC refrigerants.

C.1.c Companies working with cooling equipment using natural refrigerants

There are a rapidly increasing number of companies around the world opting for natural refrigerants to meet their cooling needs. For example, in the supermarket sector, which is a prominent user of refrigeration, there is an exponential growth in the use of equipment and refrigeration systems working with natural refrigerants.

In 2006, the number of supermarkets worldwide was estimated at 280,000, the number of minimarkets was estimated at 4 million, other facilities which had cooling condensing units was estimated to be at 34 million units. Furthermore, commercial retail stores, which had stand-alone refrigeration units (freezers, chillers and refrigerators), were estimated at 9.8 million. Vending machines and other stand-alone equipment was also evaluated to be at 20.5 and 32 million units respectively. All of this data gave an estimated refrigerant bank of approximately 340,000 MT, in 2006, for commercial cooling equipment; distributed at 46% in centralized systems, 47% for condensing units and 7% for stand-alone equipment.¹⁸ All cooling functions of this sector can be met with natural refrigerants.

There is a tremendous growth in the installation of transcritical CO₂ systems in supermarkets in many countries around the world. Europe leads the way. In the years 2005 to 2009 about 300 transcritical CO₂ systems were installed in Europe. In 2010 approximately 400 systems and in 2011 more than 800 systems were installed, bringing the total number of installed systems to approximately 2000 in European countries.¹⁹

Table 4: Examples of companies using cooling equipment with hydrocarbons and CO₂ natural refrigerants

Company	Country	Application	Notes
AEON	Japan, China, Hong Kong and Malaysia	Retailer	AEON is one of the largest retailers in Asia and is also a member of the Consumer Goods Forum. The company operates stores under several brands, including JUSCO and MaxValu. Since 2009 the company has been testing and optimizing a Sanyo CO ₂ direct expansion refrigeration system for supermarket showcases in Japan. In 2012, the company unveiled an orderly plan to go HFC-free with natural refrigerants: 10% of all new stores in 2012, 15% of all new stores in 2013, 25% of all new stores in 2014 and 100% of all new stores in 2015. The company also plans to gradually convert the refrigeration systems in its existing 3500 stores. ²⁰
Aldi Sud	Germany	Discount Supermarket	The giant German food discount chain, Aldi Sud, announced in December 2009 that as of January 2010 the company will only install CO ₂ refrigeration systems in all new stores in Germany. The company opens around 150 new stores each year. Aldi Sud contracted Carrier to install the CO ₂ systems.
Angle Vale Drakes	Australia	Supermarket	Angle Vale Drakes supermarket, opened in 2007, was the first store in Australia to use a CO ₂ refrigeration system. ²¹
Asda	United Kingdom	Supermarket	The British supermarket chain Asda is using carbon dioxide and ammonia cascade systems at a number of food distribution centers in the UK. Asda has had such systems installed since 2002 by Star Refrigeration ²²
Auchan	Hungary	Supermarket	Auchan supermarket has two stores in Hungary fitted with CO ₂ /ammonia cascading systems. Reported energy savings are at least 35% better than with comparable R404a air-cooling systems ²³

¹⁸ <http://ozone.unep.org/teap/Reports/RTOC/RTOC-Assessment-report-2010.pdf>

¹⁹ Pedersen, Per Henrik, Danish Technological Institute, "Low GWP Alternatives to HFCs in Refrigeration". 2012: p. 24

²⁰ <http://www.r744.com/news/view/3092>

²¹ www.r744.com/news/view/922

²² http://www.eurammon.com/sites/default/files/attachments/magazin_eur_081001_fin.pdf

²³ www.r744.com 2010-03-01

Table 4, cont'd

Company	Country	Application	Notes
Booths	United Kingdom	Supermarket	In 2010, Booths, a retail chain with an inventory of 26 stores in Britain, opened the first of its stores using CO ₂ for all of its refrigeration demands. Booths plan to switch to CO ₂ refrigeration in all of its stores by 2020. In addition, the company reports 45% energy savings by placing glass doors on all refrigerated cabinets. ²⁴
Ben & Jerry's	USA	Ice Cream Retailer	In 2008, the Unilever company Ben Jerry's initiated a test project in the U.S. using hydrocarbon ice cream freezer in select locations. Following the success of the test project, and the US EPA's 2011 approval of the use of hydrocarbons in freezers and domestic refrigerators, Unilever and Ben Jerry's announced plans in 2012 to only purchase hydrocarbon freezers for the US market. Ben & Jerry's has approximately 100,000 freezers in the United States. The HC freezers use 10% less energy than the company's HFC freezers.
Carlsberg	Denmark, Sweden and Switzerland	Food and beverage	Carlsberg has deployed in Denmark, Sweden, and Switzerland over 3,500 coolers using hydrocarbon technology.
Carrefour	Europe	Supermarket	In 2012 Carrefour is testing 18 sites, throughout Europe, using natural refrigerants. Two stores, in Belgium and Italy, opened in 2012 are using hybrid systems with CO ₂ and ammonia. Carrefour plans for a full rollout of all new stores being HFC-free by December 2013. ²⁵
Carrefour	France	Supermarket	A 2300 m ² Carrefour Market in Beaurans-les-Arras, opened in 2012; it is the first French supermarket to use CO ₂ transcritical cycle refrigeration. The system uses 150kg of CO ₂ . The company reports 10-15% energy savings compared to HFC-404a systems. ²⁶
Condor	Brazil	Supermarket	In 2011 Condor, the Brazilian supermarket chain, installed a subcritical CO ₂ cascade refrigeration system, developed by Bitzer and Electrofrío, in their hypermarket store in Curitiba. ²⁷ The energy savings is 20% in the freezer sector, and 5% in the overall refrigeration system. Propylene glycol is used as the heat transfer fluid, and the HFC charge is reduced by 90%.
COOP	Switzerland	Supermarket	COOP is the second largest supermarket chain in Switzerland, with over 1000 stores. ²⁸ Starting in 1998, the company began to install subcritical CO ₂ refrigeration systems. In 2004 the company installed its first direct expansion CO ₂ system, and in 2009 the company opted to make transcritical CO ₂ booster systems the standard for new and rebuilt stores. In these systems a central system cools the network of display cabinets and walk-in coolers, in both the low and medium temperature range. These systems reduce the direct CO ₂ equivalent emissions for COOP from 30,000 kg to 30 kg per year. ²⁹ The system is engineered by Frigo-Consulting AG and installed by Alpiq InTec West AG.
Countdown Auckland	New Zealand	Supermarket	In 2012 Countdown Auckland opened its new supermarket featuring a transcritical CO ₂ refrigeration system. ³⁰

²⁴ <http://www.r744.com/articles/2011-01-07-next-british-retailer-goes-co2.php>

²⁵ Greenpeace interview with Carrefour, November 2011.

²⁶ www.r744.com/news/view/3097

²⁷ <http://www.r744.com/articles/157520120119.php>

²⁸ <http://www.r744.com/articles/2009-07-28-swiss-supermarket-chain-chooses-co2.php>

²⁹ <http://www.alpiq-intec.ch/en/news-stories/stories/stories.jsp?story=tcm:122-63350>

³⁰ www.r744.com/articles/156920120111.php

Table 4, cont'd

Company	Country	Application	Notes
Danone	Denmark, Mexico and Germany	Dairy Products	Danone has 1,000 coolers using hydrocarbon technology in a number of countries, including Denmark, Mexico, and Germany.
Drakes	Australia	Supermarket	In 2008, Drakes supermarket in Australia installed a transcritical CO ₂ -only cooling system without any back-up system in its North Adelaide store. ³¹ This is the first of its kind in Australia.
Edeka	Germany	Supermarket	Since 2010, the German food retail cooperative Edeka, has been recommending CO ₂ as the company's refrigerant of choice to its self-employed shop owners. With special environmental funds, provided by the German government, it subsidizes the efforts of the independent Edeka entrepreneurs towards optimized refrigeration using natural refrigerants. One Edeka market in the north of Germany is reporting 25% energy savings running a 100% CO ₂ transcritical system. ³²
Eurospar (a division of SPAR Austria Group)	Austria	Supermarket	In 2008, the supermarket chain Eurospar, installed the chain's first transcritical CO ₂ refrigeration system in its store in Klangenfurt, Austria. Carrier Commercial Refrigeration did the installation. In 2009, the SPAR Group installed an integrated Carrier system in its store in St. Gilgen, Austria and announced plans for similar installations in four additional stores. SPAR Austria operates about 1400 stores in Austria, as well as stores in Northern Italy, Slovenia, Hungary, Czech republic and Croatia. ³³
Fakta	Denmark	Supermarket	In 2011, the Fakta supermarket chain had 61 stores operating with transcritical CO ₂ refrigeration systems. It is reported that the company's second generation transcritical CO ₂ booster systems delivers 10% energy savings over similar non-CO ₂ systems. ³⁴
Foodland IGA	Australia	Supermarket	Opened in 2009, the Foodland IGA supermarket in Adelaide, features CO ₂ refrigeration. The company aims to be among the "greenest" supermarkets in the country. ³⁵
Harrods	United Kingdom	Supermarket	In 2011, the world-renowned department store replaced its aging HCFC/HFC refrigeration system in the store's Food Hall with a transcritical CO ₂ refrigeration system to cool colds rooms and food display cabinets. Waste heat from the cooling packs is used for generating hot water for the store. ³⁶

³¹ www.r744.com/news/news_ida302.php.

³² <http://www.r744.com/articles/2010-05-26-new-industry-report-r744-favourite-option-for-german-retailers-aldi-sued-edeka-tegut-tengelmann.php>

³³ [http://www.carrier-refrigeration.com/News.824.0.html?&tx_ttnews\[tt_news\]=31&cHash=9f3793f77e](http://www.carrier-refrigeration.com/News.824.0.html?&tx_ttnews[tt_news]=31&cHash=9f3793f77e)

³⁴ <http://www.r744.com/articles/150820111028.php>

³⁵ www.r744.com/news/view/922

³⁶ www.r744.com/articles/154820111213.php

Table 4, cont'd

Company	Country	Application	Notes
Heineken	Global	Food and beverage	<p>Aiming for a 50% reduction in the carbon footprint of its installed fridge base by 2020, Heineken is rolling out hydrocarbon refrigerant bottle coolers at a global scale. In 2010, Heineken sourced approximately 130,000 of these hydrocarbon bottle coolers, and have an intention to start a global rollout in 2012.</p> <p>Heineken's policy is that, whenever technically and legally possible, every new fridge it buys will include hydrocarbon refrigerant, LED illumination and energy management system thermostats. With these three elements, the company expects energy reduction of at least 30%, as well as lower maintenance costs and a longer fridge lifespan.</p> <p>The brewer has been working with suppliers Frigoglass and Klimasan to meet their specifications globally.³⁷</p>
ICA Sweden	Sweden	Supermarket	<p>ICA Sweden has around 30 stores that use 100% natural coolants, and the number is growing. Since 2010, the natural refrigerant of choice has been CO₂; ICA uses transcritical-CO₂ systems in all new stores and larger store renovations.³⁸</p> <p>Large stores primarily use glycol, which circulates in the system and cuts the amount of cooling agents. Glycol is used in the refrigeration systems and carbon dioxide is used for freezers at ICA Maxi, Kvantum and Supermarket.</p>
Lidl	Germany	Supermarket	<p>In 2010, Lidl decided to install integrated heat-cooling systems based on hydrocarbons in all new stores and to "equip about 200 new stores with R290 technology by 2012".³⁹ The systems use R290 cooling cabinets. Furthermore, waste heat from the cooling cabinets is recycled and used for heating the store. In 2011, Lidl opened a new store with the integrated system in Achim-Baden, Germany; Lidl reports a 30% reduction in greenhouse gas emissions, and 10% energy savings for this store.</p>
Makro South Africa	South Africa	Supermarket	<p>Makro SA has up to 15 stores in South Africa. In 2011, for three of its newest stores, the company installed a combination of ammonia and CO₂ refrigeration solutions to meet 100% of its cooling needs. In addition, the recaptured heat from the cooling plant is used to provide hot water and heat as required in the store.⁴⁰</p>
Marks & Spencer	Global	Supermarket	<p>Starting in 2010, Marks & Spencer plans to have all its new supermarkets in the world use CO₂ and/or hydrocarbon based refrigeration. The company is training technicians in developing countries in the use of natural refrigerants.</p> <p>Furthermore, in 2011 the company opened its most carbon-efficient store at Stratford City, close to the 2012 Olympic Park. The 136,000 sq-ft store is the third largest M&S store and uses hydrocarbon R290 propane in its refrigeration system as well as CO₂ in its cooling circuits.⁴¹</p>
Metro	Germany	Supermarket	<p>Metro has five stores in Germany and Denmark using CO₂ refrigeration technology.</p>

³⁷ <http://www.sustainabilityreport.heineken.com/2010/brewing-a-better-future/green-commerce.html>

³⁸ Communication between ICA Sweden and Greenpeace, May 2012.

³⁹ <http://www.hydrocarbons21.com/news/view/2619>

⁴⁰ <http://www.r744.com/articles/2010-11-24-makro-south-africa-chooses-co2-and-ammonia-for-its-new-stores.php>

⁴¹ <http://www.hydrocarbons21.com/news/view/2705>

Table 4, cont'd

Company	Country	Application	Notes
Migros Supermarket	Switzerland	Supermarket	Since 2002, Migros Supermarket has installed over 150 CO ₂ refrigeration systems in its supermarket stores across Switzerland. By 2010, CO ₂ refrigeration systems accounted for 10% of the company's store inventory, including 47 transcritical systems. ⁴²
Morrisons	United Kingdom	Supermarket	By the end of 2009, Morrisons planned to have 20 of its 418 UK stores use CO ₂ refrigeration. In 2011, Morrisons opened a supermarket using hydrocarbon refrigerants throughout the store. ⁴³
Nestlé	Global	Food and beverage	Nestlé, the world's largest food processing company, is committed to phasing out all fluorocarbon refrigerants. On October 1, 2001, the company announced "wherever possible, Nestlé will use natural refrigerants in new industrial refrigeration systems" with a preference for "using the combined characteristics of ammonia and carbon dioxide." Globally in 2012, Nestlé's uses natural refrigerants in 90% of its industrial cooling for food processing. In addition, Nestlé has installed over 11,000 hydrocarbon ice cream freezers in Europe, Australia, Spain, Malaysia, Chile and the United States. ⁴⁴
Netto	United Kingdom / Denmark	Supermarket	Netto is a Danish discount supermarket chain with about 200 stores in the UK. The company has installed CO ₂ refrigeration systems in all of its Danish fresh meat warehouses, as well as in one 21,500 sq-meter meat warehouse in the UK. ⁴⁵
Pick n Pay	South Africa	Supermarket	In 2009, Pick n Pay one of the largest supermarket chains in Southern Africa, with the help of GIZ Proklima, converted two supermarket stores in climatically different zones in South Africa (Johannesburg and Cape Town) to a cascade system with ammonia and CO ₂ . ⁴⁶
Prodega Cash & Carry	Switzerland	Supermarket	In 2011, Prodega opened in the town of St Blaise a 3000 sq-meter store featuring transcritical CO ₂ refrigeration combined with a heat recovery system that uses the waste heat for adsorption cooling, which in turn increases the cooling capacity of the CO ₂ refrigeration system. The system was designed by Frigo-Consulting. ⁴⁷
REWE	Germany	Supermarket	Europe's third largest food trader announced in 2006 that from 2008 onward, it will only use CO ₂ (R744) refrigeration in new small-sized supermarkets in Germany. ⁴⁸ In 2010 REWE's Berlin-Rudow store received a gold award from the German Society for Sustainable Building (DGNB), the first supermarket to receive the award. The store uses a Carrier designed CO ₂ OLtec refrigeration system with plug-in display cabinets using R290 to cool fresh and frozen produce. The store also incorporates innovative heat recovery geothermal technology for increased efficiency. ⁴⁹

⁴² <http://beta.r744.com/knowledge/papersView/785>

⁴³ <http://oz-chill.com/morrisons-supermarket-to-use-hydrocarbons-throughout-the-store/>

⁴⁴ <http://beta.hydrocarbons21.com/news/view/3179>

⁴⁵ <http://www.r744.com/articles/142120110614.php>

⁴⁶ <http://www.gtz.de/de/dokumente/giz2011-en-proklima-projectsheet-southafrica.pdf>

⁴⁷ <http://www.r744.com/news/view/1440>

⁴⁸ www.r744.com/news/news_ida260.php

⁴⁹ <http://www.r744.com/articles/2010-01-13-carrier-corporation-installs-award-winning-co2-system-for-rewe-phi>

Table 4, cont'd

Company	Country	Application	Notes
Sainsbury's	United Kingdom	Supermarket	Sainsbury's plans to convert all of its stores from HFCs to natural refrigerants (primarily CO ₂) by 2030. By the end of 2010, 9 stores in the United Kingdom were using CO ₂ transcritical refrigeration systems. In 2012 Sainsbury's completed its 100th CO ₂ installation. The company estimates that it has over 16,800 chilled and freezer cabinets connected to these systems, which contain 75 tonnes of CO ₂ and saves in emissions 250,000 tonnes of CO ₂ -e when compared to using HFC 404a. ⁵⁰
Sobeys	Canada	Supermarket	Sobeys, Canada's second largest food retailer with more than 1300 stores across the country, plans on transitioning all new stores to CO ₂ refrigeration. Sobeys was the first to deploy transcritical CO ₂ refrigeration in North America in 2006, starting in Quebec, and has gone HFC-free in new stores in Quebec since 2009. ⁵¹ To date the company has 23 IGA stores in Quebec with transcritical systems and expects to have 31 transcritical stores by the end of 2012. ⁵² Sobeys plans on transitioning all stores, including older stores, to HFC-free technology within 15 years.
Star Market	United States	Supermarket	In 2010, the Star Market store in Chestnut Hill, Massachusetts, received the US EPA's coveted GreenChill Partnership Platinum Store award for reducing the HFC-404a charge by 90%, from 4000 lbs. to 270lbs, by installing a glycol and CO ₂ secondary cooling system. Glycol heat-exchange fluid is used for cooling display cabinets, and CO ₂ fluid is used for freezer cases. ⁵³
Supervalu (Albertsons)	United States	Supermarket	In 2012, Supervalu, the mega American supermarket chain, opened its expanded 40,300 sq. ft. Albertson's store in Carpinteria, California, using natural refrigerants. A primary ammonia cooling system located in an outdoor enclosure chills the cascading CO ₂ secondary cooling system that is distributed throughout the store. A food display cabinet uses propane. The company reports that the ammonia system is "outperforming the standard HFC-407a system far beyond what was expected." ⁵⁴
The Co-operative Food Group	United Kingdom	Supermarket	The British retailer, the Co-operative Food Group, plans on all new refrigeration installations to be HFC-free by 2015 and all older store retrofits to be HFC-free by 2030. In 2010, the company installed hydrocarbon refrigeration units in 290 of its stores, and as of 2011, the company has implemented an initiative for all new stand-alone chillers and freezers to be hydrocarbon-based. Also in 2011, the retailer retrofitted 3 stores with a CO ₂ based refrigeration systems. ⁵⁵
Tesco	United Kingdom	Supermarket	In 2009, Tesco had five stores in the United Kingdom using CO ₂ -based refrigeration systems. By the end of 2012, Tesco plans to have 150 stores using CO ₂ refrigeration. Outside the United Kingdom, Tesco has installed or is testing CO ₂ refrigeration in stores in Korea, Thailand, Hungary, the United States, Turkey, Malaysia, Czech Republic, Slovakia, and Poland.

⁵⁰ www.r744.com/news/view/1635

⁵¹ Greenpeace interview with Sobeys, August 2011.

⁵² <http://supermarketnews.com/blog/sobeys-shows-how-forestall-climate-change>

⁵³ <http://www.r744.com/articles/2010-01-11-us-store-granted-highest-award-thanks-to-co2-refrigeration.php>

⁵⁴ Greenpeace correspondence with Supervalu, July and September 2012.

⁵⁵ http://www.co-operative.coop/Corporate/sustainability/2011/downloads/sr2011_Climate_change.pdf

Table 4, cont'd

Company	Country	Application	Notes
Tengelmann Group	Germany	Supermarket	In 2008, the German food retailer, Tengelmann opened its first climate-friendly supermarket based on a CO ₂ refrigeration system in Mülheim an der Ruh, Germany. The store which also boasts geothermal heating, waste heat from the refrigeration system, solar panels and energy efficient display cases have made this “store the most energy-friendly supermarket in Germany.” ⁵⁶ The Tengelmann Group is using this initial pilot project to serve as a blueprint for further projects using R744 in Tengelmann supermarkets. ⁵⁷
tegut...gute Lebensmittel	Germany	Supermarket	In 2008, tegut...gute Lebensmittel, a German food retail chain, opened in Lorsch, Germany its first supermarket operating completely with CO ₂ refrigeration. The transcritical system has a CO ₂ OLtec refrigeration system and e*cube energy-saving display cases provided by the Carrier Corporation. Due to the positive results from this first store, in 2010, tegut...gute Lebensmittel came to an agreement with Carrier to provide 50 more stores with the CO ₂ OLtec refrigeration systems and e*cube refrigerated display cabinets and freezers. The endeavors, which will be completed in 2012, is expected to yield up to 50% energy savings and result in a reduction of approximately 3500 metric tons of CO ₂ -eq each year (equivalent to 1900 cars on the road). ⁵⁸
Tesco China	China	Supermarket	In 2012, Tesco China opened in Beijing its 2nd store using CO ₂ cascade system. The first store is in Shanghai. The CO ₂ system enables the company to reduce the HFC charge from 1500 Kg to 200 Kg. ⁵⁹
Tesco Express	Hungary	Supermarket	By 2011, Tesco Hungary completed 33 CO ₂ transcritical and CO ₂ /NH ₃ refrigeration installations. An innovative “Three Level System” (TLS) combines air-conditioning with mid-level temperature and low-level temperature food cooling. ⁶⁰
Tesco Lotus	Thailand	Supermarket	Tesco Lotus in Thailand is the first supermarket in Asia to have installed a cascade CO ₂ system. It is built by the Australian company, Frigrite, and installed by Carrier.
Verdemar	Brazil	Supermarket	In 2010, the Brazilian supermarket chain opened a 6,000m ² store featuring a CO ₂ cascade refrigeration system. The store is forecasted to slash one-fifth off its energy consumption in comparison with other Verdemar stores with the same cooling capacity using HCFC 22. In 2010 Verdemar was also planning to open a CO ₂ food distribution center. ⁶¹

⁵⁶ <http://tengelmann.de/press/pressemitteilungen-ausgabe/archive/2008/dezember/01/article/germanys-first-climate-friendly-tengelmann-store-opens-on-december-2-2008.html>

⁵⁷ <http://www.r744.com/articles/2010-05-26-new-industry-report-r744-favourite-option-for-german-retailers-aldi-sued-edeka-tegut-tengelmann.php>

⁵⁸ http://www.carrier-refrigeration.com/News.824.0.html?&tx_ttnews%5Btt_news%5D=213&cHash=070895712d1a196c9ec44ec221833c4d

⁵⁹ www.r744.com/news/1626/

⁶⁰ Greenpeace correspondence with Tesco Hungary, October 2010.

⁶¹ <http://oz-chill.com/turkish-and-brazilian-supermarket-debut-with-natural-refrigerants>

Table 4, cont'd

Company	Country	Application	Notes
Waitrose	United Kingdom	Supermarket	<p>The UK company Waitrose, owned by the John Lewis Partnership, to date has “26 stores operating on a complete hydrocarbon integralized solution. This water-cooled/propane natural refrigerant system will be installed within all their Waitrose shops by 2020 and a program of work is underway to achieve this.”⁶² The company estimates that the propane refrigeration technology will reduce its carbon footprint by 20%.⁶³</p> <p>The system is based on a combination of high-efficiency air-cooled chillers supplied by Klima-therm and manufactured by Geoclima that utilize R290 propane and use water as the condensing medium to supply the Carter Retail Equipment integrated cabinets operating on R1270 propene hydrocarbon-based scroll compressors. It makes use of split coils to keep the propene charge under 400 g, together with liquid pump amplification and floating head pressure and conventional free cooling below 18°C. The system design allows for the harnessing of heat from the integral refrigeration units to deliver warmth into the space between cabinets, in order to offset the in store “cold aisle” effect. This helps boost efficiency and overcomes the need for a separate heating system.⁶⁴</p>
Walmart	United States	Retailer	<p>Walmart is in the R&D stages of a transition to non-HFC technology; by 2012 the company will have a proto-pilot program that will consist of 30-40 new and retrofitted stores running on a secondary loop CO₂ system. The secondary loop CO₂ system will reduce the HFC refrigerant charge from 4000lbs to 200lbs in each store.⁶⁵</p>
Warehouse	New Zealand	Supermarket	<p>First supermarket in New Zealand to install (2006) a cascade CO₂ system, that uses CO₂ for cooling display cabinets and cold rooms for the low temperatures, and propylene for the medium temperatures.⁶⁶</p>
Wegmans	United States	Supermarket	<p>In 2010 the new Wegmans store in Woodmore, MD, opened with freezer cases using CO₂ refrigerants. In 2012 Wegmans opened a new distribution center with CO₂ refrigerants.⁶⁷</p>
Woolworths	Australia	Food Retailer	<p>Australia’s largest food retailer, Woolworths, announced that it plans to install CO₂ cascade systems in new stores after the success of its pioneer “green supermarket” in Sydney.⁶⁸</p>

⁶² www.ior.org.uk/app/images/.../King3rdFeb2011%20Bham.pdf

⁶³ www.hydrocarbons21.com 2010-03-29

⁶⁴ www.hydrocarbons21.com 2009-08-12

⁶⁵ Greenpeace interview with Walmart, September 2011.

⁶⁶ <http://www.r744.com/articles/156920120111.php>

⁶⁷ http://www.wegmans.com/webapp/wcs/stores/servlet/CategoryDisplay?storeId=10052&identifier=CATEGORY_4007

⁶⁸ www.r744.com/news/news_ida302.php Industry Visits Australia’s first CO₂ only supermarket

C.2 Manufacturers/distributors of commercial cooling equipment using natural refrigerants

With the growing global demand for sustainable cooling equipment, there is a steady growth in the number of companies producing and marketing equipment with natural refrigerants.

Table 5: Examples of companies producing and/or marketing cooling equipment with natural refrigerants (hydrocarbons and CO₂)

Company	Country	Equipment Details
AHT Austria	Austria	AHT company of Austria is a major manufacturer of plug-in-type supermarket cabinets. The company is producing a 724L net freezer cabinet using 120g of R290. In 2007, the company designed a similar cabinet with fresh food compartment. ⁶⁹
AHT UK	United Kingdom	In 2009, AHT launched its propane Multidecks, open-fronted display coolers for snack foods, soft drinks, and dairy products. AHT Cooling Systems is one of the largest UK wholesalers of commercial refrigeration products. ⁷⁰
Alpiq Intec	Switzerland	Alpiq Intec is a building and facilities management provider in Switzerland. Under its Refrigeration Technology Department, Alpiq Intec installed the first transcritical-booster CO ₂ refrigeration system for the Swiss retail-giant COOP in 2009. ⁷¹
Bar Fridges	Australia	Markets a range of “Rhino” brand bar refrigerators using hydrocarbons. Units include small mini compact bar fridges, glass door wine fridges, alfresco fridges, beer fridges and upright commercial display fridges. ⁷²
Binzhou Sky Rainbow	China	Binzhou, a manufacturer of bottle coolers and small freezers, is in the process (2012) of developing hydrocarbon products, for an expected launch in 2013 for European market. ⁷³
Blupura	Italy	The Italian company Blupura produces the R290 FONTEMAGNA water cooler: “well insulated ice-bank for high volume supply of cold, still and sparkling water, with a capacity of 15 liters per hour.” ⁷⁴ In 2010, the company launched a new range of hydrocarbon counter top water coolers for restaurant, office and home use. ⁷⁵
Caravell (a division Metalfrio Solutions)	Denmark	Since 2009, Caravell has been producing a 400-liter capacity refrigerator with CO ₂ as the system refrigerant. ⁷⁶ This unit also has a 45% lower pull down time (the time necessary to refrigerate a complete load of beverages). Caravell also markets a 74-liter open-top bottle cooler using hydrocarbons. ⁷⁷
Carter Retail Equipment	United Kingdom	Carter Retail Equipment, developed specifically for the UK retailer Waitrose, a range of display cabinets with hydrocarbon refrigerant water cooled condensers, which is an important component of a newly developed integralized refrigeration system using hydrocarbons as the overall system refrigerant. ⁷⁸

⁶⁹ TemaNord. 2007: “Potent Greenhouse Gases: Ways of Reducing Consumption and Emission of HFCs, PFCs 7 SF6”: report prepared for the Nordic Council of Ministers p. 31

⁷⁰ www.hydrocarbons21.com 2009-04-27

⁷¹ <http://www.alpiq-intec.ch/en/news-stories/stories/stories.jsp?story=tcm:122-63350>

⁷² Greenpeace correspondence with Bar Fridges, April 2012.

⁷³ <http://www.hydrocarbons21.com/news/view/3164>

⁷⁴ www.hydrocarbons21.com 2010-03-01

⁷⁵ <http://www.hydrocarbons21.com/news/view/2605>

⁷⁶ <http://www.caravell.dk>

⁷⁷ TemaNord. 2007: “Potent Greenhouse Gases: Ways of Reducing Consumption and Emission of HFCs, PFCs 7 SF6”: report prepared for the Nordic Council of Ministers p. 27

⁷⁸ www.ior.org.uk/app/images/.../King3rdFeb2011%20Bham.pdf

Table 5, cont'd

Company	Country	Equipment Details
Carrier Corp and Carrier Commercial Refrigeration	US/Global	<p>A United Technologies Company, Carrier is the world's largest producer of heating, ventilation, air-conditioning and refrigeration systems.⁷⁹ Carrier has approximately 41,000 employees worldwide and operations in more than 170 countries.⁸⁰ Under the CO₂OLtec label, the company has developed CO₂ refrigeration systems for supermarkets and other large applications. Carrier developed a two-step technology with the refrigerant that allows the pressure on the supermarket shop floor to be kept at around 40-bars with only the plant areas requiring higher pressures.⁸¹</p> <p>The Carrier CO₂ integrated system uses one central compressor pack device to operate the air conditioning and heating equipment as well as the refrigerated cabinets. "With one device managing all these functions efficiently together, energy consumption can be optimized. In addition, the waste heat from the system can be reused in operations, reducing CO₂ emissions."⁸²</p> <p>Carrier also produces hydrocarbon based refrigerated cases and display cabinets.</p>
Criocabin	Italy/Global	<p>Criocabin is an Italian manufacturer of cold-rooms. Since January 2012, the entire product range of Criocabin has been converted HFC-free polyurethane, using water-expanding components instead of HFC gases.</p> <p>Furthermore, Criocabin uses CO₂ cascade systems for most of its new cold-room installations. In the near future, the company also plans to use water-expanding agents in their cold-room refrigeration circuits. This is a technology that Criocabin has been using in cabinet production since 2009.⁸³</p>
CSC Group	Canada	<p>CSC Group, developed and manufactures a patented CO₂ based "Eco2-System" for supermarkets. In addition to reducing greenhouse gas emissions, the system reduces energy costs by recapturing heat from the cooling system, and using it for heating the store. The company estimates that if all 6,500 grocery retailers in Canada would use its Eco2-System, the GHG emission reduction would be equivalent to "taking 2 million cars off the road".⁸⁴ The cost of maintaining the Eco2-System is reported to be significantly less than competitive systems using HFCs.</p> <p>In 2011, CSC installed the world's first 100% CO₂ ice rink, in the Marcel Dutil Arena of the town of Les Coteaux, Quebec. The company's "Eco-2-System" uses only CO₂, replacing both the use of HCFC-22 and ammonia, in a transcritical refrigeration cycle. The system uses a Danfoss ICMTS valve to regulate the flow of CO₂.⁸⁵</p>
Derby (a division Metalfrio Solutions)	Middle East, Europe, and Brazil.	<p>Derby, a commercial refrigeration manufacturer supplying hydrocarbon-based refrigerators, coolers and storage cabinets⁸⁶. The company also produces CO₂ commercial coolers for Coca-Cola⁸⁷.</p>

⁷⁹ <http://www.r744.com/articles/2009-05-25-coming-soon-carrier-co2-solutions-for-industrial-and-commercial-use.php>

⁸⁰ [http://www.carrier-refrigeration.com/News.824.0.html?&tx_ttnews\[tt_news\]=31&cHash=9f3793f77e](http://www.carrier-refrigeration.com/News.824.0.html?&tx_ttnews[tt_news]=31&cHash=9f3793f77e)

⁸¹ http://www.appliancedesign.com/CDA/Articles/Feature_Article/BNP_GUID_9-5-2006_A_1000000000000558309 Appliance Design, March 31, 2009

⁸² [http://www.carrier-refrigeration.com/News.824.0.html?&tx_ttnews\[tt_news\]=31&cHash=9f3793f77e](http://www.carrier-refrigeration.com/News.824.0.html?&tx_ttnews[tt_news]=31&cHash=9f3793f77e)

⁸³ <http://www.criocabin.com/index/english/news.html>

⁸⁴ <http://www.r744.com/articles/2009-06-17-canadian-firm-launches-supermarket-co2-system.php>

⁸⁵ <http://www.r744.com/news/view/3096>

⁸⁶ Danish Environment Ministry, "Low GWP Alternatives in Refrigeration", 2012, p.12 (<http://www.mst.dk/Publikationer/Publications/2012/June/978-87-92903-15-0.htm>)

⁸⁷ <http://www.metalfrio.com.br/site/derby/en/news/news/news.aspx>

Table 5, cont'd

Company	Country	Equipment Details															
DSI	Denmark	DSI designs and manufactures plate freezers for on-shore and marine installations for transporting and processing seafood. The company offers CO ₂ plate freezers for installation worldwide. Currently, the company has over 500 CO ₂ plate freezers in operation in Europe. According to DSI, the change from HCFCs to CO ₂ freezers on board ships yields greater efficiency, as CO ₂ freezers can attain cooler temperatures (CO ₂ reaches -50°C, while HCFCs reach -38 to -40°C). ⁸⁸															
Earthcare Products Ltd.	United Kingdom	Earthcare Products Ltd. is marketing a wide range of commercial cooling equipment using hydrocarbons:															
		<table border="1"> <thead> <tr> <th>Range of wall-mounted and ceiling-mounted split air-conditioners</th> <th>Water coolers</th> <th>Glass door merchandiser</th> </tr> </thead> <tbody> <tr> <td>Dehumidifiers</td> <td>Chest chill cabinets</td> <td>Sliding door display coolers</td> </tr> <tr> <td>Range of air-cooled chillers: largest model offer 1,265 kW</td> <td>Ice cream conservators</td> <td>Defrost type freezer chillers</td> </tr> <tr> <td>Mini bars</td> <td>Bottle chillers</td> <td>Freezers</td> </tr> <tr> <td>Deli display cabinets</td> <td>Wine cooler dispensers</td> <td>Multi-deck display cabinets</td> </tr> </tbody> </table>	Range of wall-mounted and ceiling-mounted split air-conditioners	Water coolers	Glass door merchandiser	Dehumidifiers	Chest chill cabinets	Sliding door display coolers	Range of air-cooled chillers: largest model offer 1,265 kW	Ice cream conservators	Defrost type freezer chillers	Mini bars	Bottle chillers	Freezers	Deli display cabinets	Wine cooler dispensers	Multi-deck display cabinets
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Elcold	Denmark	Elcold is a manufacturer of chest freezers and coolers for both commercial and domestic applications. In the XLE-range, they have increased the insulation to 100 mm. This, in combination with an environmentally friendly refrigerant and optimized compressor, saves on energy and direct global warming impacts. ⁸⁹															
Enex	Italy	Producers of commercial refrigeration systems for supermarkets, hypermarkets, cold stores and freezing tunnels using CO ₂ as the system refrigerant. The company specializes in transcritical booster systems as well as cascade systems. Their refrigeration systems can also be implemented to use system "waste" heat for heating purposes in stores.															
Fogel Group	Guatemala, Ecuador and Colombia	Produces cooling equipment with cyclopentane for the insulation and R-290 for refrigerant. ⁹⁰															
Foster Refrigeration Ltd.	United Kingdom	Refrigerated cabinetmakers primarily for the food industry, Foster Refrigeration was the first commercial manufacturer to introduce hydrocarbons (R290) into food service cabinets. The company has produced hydrocarbon equipment since 1996. Currently (April 2012), Foster Refrigeration has 13 different models of refrigerated counters and freezers, under it's Eco Pro Counters line, which give the option of using hydrocarbons as the refrigerant at no additional cost. The Eco Pro Counters line also boasts a 30% reduction in energy usage from previous models. ⁹¹ The company operates worldwide with offices in the United Kingdom, France, Germany, Italy, Austria, and Spain.															

⁸⁸ <http://www.dsi-as.com/>

⁸⁹ <http://www.elcold.com/GB/Products/Low%20Energy%20Chest%20Freezers.aspx>

⁹⁰ <http://www.fogel-group.com/en/content/our-commitment-environment>

⁹¹ <http://www.fosterrefrigerator.co.uk/Foster-products.asp?id=327>

Table 5, cont'd

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Framec	Italy/Global	<p>Framec is an Italian manufacturer of high quality commercial refrigeration and freezer units. Under its Green Emotions product range, the company produces refrigerators and freezers in various sizes with high performance compressors using hydrocarbons (R600s and R290). The estimated energy savings in comparison to similar HFC models are approximately 27-53%, depending on the unit size, resulting in an estimated 370-470 kg of CO₂ emission reduction, per unit per year.⁹²</p>																																																															
Frigoglass	Greece	<p>The Greek manufacturer Frigoglass in 2009 launched its Ecocool range of cold drink dispenser equipment, using natural refrigerants R290, R600a, or R744 as well as the use of natural substances in the insulation.⁹³ According to the company, the Ecocool hydrocarbon coolers consume up to 50% less energy than equivalent units produced with HFCs 10 years ago.</p> <table border="1"> <thead> <tr> <th>UNIT</th> <th>R134</th> <th>HC</th> </tr> </thead> <tbody> <tr> <td>FV280</td> <td>5.99</td> <td>3.59</td> </tr> <tr> <td>SUPER 5</td> <td>3.66</td> <td>3.19</td> </tr> <tr> <td>ACTIVATOR 700</td> <td>6.35</td> <td>4.20</td> </tr> <tr> <td>ACTIVATOR 500</td> <td>6.59</td> <td>3.85</td> </tr> <tr> <td>EASYREACH EXPRESS</td> <td>9.88</td> <td>6.04</td> </tr> <tr> <td>COUNTER EXPRESS</td> <td>4.20</td> <td>3.55</td> </tr> <tr> <td>SMARTOP 20</td> <td>1.16</td> <td>1.00</td> </tr> <tr> <td>MV40</td> <td>2.10</td> <td>1.67</td> </tr> <tr> <td>CMV100</td> <td>2.3</td> <td>1.80</td> </tr> <tr> <td>CMV105</td> <td>3.1</td> <td>2.80</td> </tr> <tr> <td>MV250</td> <td>5.00</td> <td>4.70</td> </tr> <tr> <td>OPXS</td> <td>6.16</td> <td>4.09</td> </tr> <tr> <td>SLIM</td> <td>8.00</td> <td>3.50</td> </tr> <tr> <td>CMV375</td> <td>3.40</td> <td>2.30</td> </tr> <tr> <td>CMV446</td> <td>5.16</td> <td>4.66</td> </tr> <tr> <td>CMV550</td> <td>6.40</td> <td>5.60</td> </tr> <tr> <td>SUPER 7</td> <td>7.14</td> <td>6.10</td> </tr> <tr> <td>SUPER 8</td> <td>6.80</td> <td>5.19</td> </tr> <tr> <td>SUPER 800</td> <td>11.40</td> <td>10.94</td> </tr> <tr> <td>SUPER 122</td> <td>15.90</td> <td>12.50</td> </tr> </tbody> </table> <p>The company has a client base of 15 countries around the world, and customers include Coca-Cola bottlers (Coca-Cola Hellenic, Coca-Cola Enterprises, Coca-Cola Amatil, Coca-Cola Sabco), international brewers (Heineken, Carlsberg, SAB Miller, ABInbev, Efes) and dairy companies (Nestlé, Danone).</p> <p>With a market share in 2008 reaching 20%, Frigoglass is the global market leader in commercial refrigeration with operations in 15 countries across four continents. Frigoglass has production hubs in Romania, Russia, Turkey, India, China, Indonesia, South Africa, and Nigeria.⁹⁴</p>	UNIT	R134	HC	FV280	5.99	3.59	SUPER 5	3.66	3.19	ACTIVATOR 700	6.35	4.20	ACTIVATOR 500	6.59	3.85	EASYREACH EXPRESS	9.88	6.04	COUNTER EXPRESS	4.20	3.55	SMARTOP 20	1.16	1.00	MV40	2.10	1.67	CMV100	2.3	1.80	CMV105	3.1	2.80	MV250	5.00	4.70	OPXS	6.16	4.09	SLIM	8.00	3.50	CMV375	3.40	2.30	CMV446	5.16	4.66	CMV550	6.40	5.60	SUPER 7	7.14	6.10	SUPER 8	6.80	5.19	SUPER 800	11.40	10.94	SUPER 122	15.90	12.50
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⁹² <http://www.framec.it>

⁹³ Greenpeace correspondence with Frigoglass, 2011-2012.

⁹⁴ www.hydrocarbons21.com/content/articles/2009-07-10-greek-firm-launches-complete-hfc-free-coolers.php

Table 5, cont'd

Company	Country	Equipment Details
Frigor	Denmark	Manufacturer of hydrocarbon domestic freezers.
Frost-Trol	Spain	Frost-Trol manufactures a line of CO ₂ based plug-in refrigeration cabinets under the brand "frost CO ₂ ". Products include serve-over, multideck and island cabinets. In 2010, about 40 stores in Denmark were operating with Frost-Trol R744 equipment. ⁹⁵
Gram Commercial	Denmark	Produces hydrocarbon commercial refrigeration kitchen equipment (refrigerators, freezers and bottle coolers), which are marketed in Sweden, Denmark, and Norway. ⁹⁶
Green & Cool	Nordic Countries and Switzerland	Manufacturer of environmentally friendly refrigeration systems, as well as air-conditioning, industrial processes and heat pumps. Has over 300 CO ₂ transcritical units installed or under construction in Europe. Manufactures "CO ₂ Mistral CCU", a single temperature range unit with integrated gas cooler/condenser, which can be configured as chiller, freezer or air conditioner. Mistral CCU is suitable for a variety of settings, including supermarkets, convenient stores, gas stations, restaurants, hospitals, hotels and industrial use. ⁹⁷
George Barker & Co. (EPTA)	United Kingdom	<p>The George Barker & Co, a brand of the EPTA Group, manufactures integral and indirect display cases mainly for food and beverages, as well as complete refrigeration installations for supermarkets and hypermarkets.</p> <p>Under the EptaGreen line, the company produces CO₂ cascade compressor packs, which are HFC-free alternatives and have better system efficiency. These compressor packs are used as components in commercial refrigeration installations.</p> <p>The company also produces a product called the Sound Green Energy unit, which is a plug-in, built-in refrigerated counter unit that runs on 100% propane as the unit refrigerant. The unit has a highly efficient compressor and if fitted with an inverter, can save about 25% of energy compared to other counters of the category.⁹⁸</p>
Haglund Industri	Sweden	Produces hydrocarbon professional kitchen refrigerators and freezers. ⁹⁹
Hill Phoenix	US/Global	Hill Phoenix, a Dover company, is a large manufacturer of refrigerated display cases, refrigeration systems, specialty coolers, and walk in coolers. The company was instrumental in having the US EPA approve the use of CO ₂ -based refrigeration under the SNAP Program. In 2011 Dover acquired the Danish Advansor A/S company, which specializes in the design and manufacture of HFC-free, CO ₂ transcritical refrigeration and heat pump systems for supermarkets and light industrial applications. "Advansor and Hill PHOENIX combined have more than 550 CO ₂ systems operating in supermarkets in the United States, Europe and Canada, making them the largest manufacturer of CO ₂ refrigeration systems in the world." ¹⁰⁰

⁹⁵ <http://www.r744.com/articles/142920110701.php>

⁹⁶ TemaNord. 2007: "Potent Greenhouse Gases: Ways of Reducing Consumption and Emission of HFCs, PFCs 7 SF6": report prepared for the Nordic Council of Ministers p. 29

⁹⁷ www.r744.com/articles/157320129117.php

⁹⁸ <http://www.georgebarker.co.uk/Ecopolicy.pag>

⁹⁹ www.r744.com/articles/157320129117.php

¹⁰⁰ www.hillphoenix.com (11-07_Advansor-Acq_Pubs&WebRelease.pdf)

Table 5, cont'd

Company	Country	Equipment Details
Husky Group	UK/Global	The Husky Group markets hydrocarbon-based ice cream displayed cabinets, and upright and under the counter bottle coolers. In 2009, the company introduced the highly efficient Intelligenza freezer cabinet that uses propane, and features new electronics with soft start compressor technology. ¹⁰¹ The company also upgraded its top-of-the-range open-fronted multideck chiller cabinets to using propane. This provides “smaller retailers and convenience stores the same advantages as large supermarkets, to minimize both direct and indirect emissions associated with their refrigeration.” ¹⁰²
Infrico	Spain/Global	Infrico, in 2012, is developing a full product range of R290 and R660a freezers for its customers in Europe, Middle East and Asia. Expected launch is 2013. ¹⁰³
Interlevin Group	UK/Europe	The Interlevin Group is the United Kingdoms largest wholesaler of commercial refrigeration and the largest commercial cabinet wholesaler in Europe. The company has produced hydrocarbon equipment since 1995. For some of the brands offered by the Interlevin Group see the following tabs in this table: Caravell, Criocabin, Elcold, Framec and Staycold.
Johnson Controls	Global	Under the brand “SA Blight”, Johnson Controls produces a series of hydrocarbon chillers with secondary coolants for light industrial applications. The hydrocarbon refrigerants used most prominently are propane, isobutane and propylene, but the company also works with other hydrocarbon refrigerants, such as ethane, ethylene, and helium. According to the company, “Hydrocarbons have no compatibility issues with different metals and therefore commonly used compressors can be used with these refrigerants. The chillers produced by Johnson Controls are using commonly used semi-hermetic compressors in collaboration with our suppliers for these products. Propane is the most often used refrigerant for chillers and heat pumps (up to about 55°C) and isobutane is used for the high temperature heat pumps (up to 95°C).” The company also produces CO ₂ cascading and trans-critical systems, as well as ammonia and water-cooling systems. ¹⁰⁴
Klimasan (a division Metalfrio Solutions)	Turkey, Middle East and Europe	Klimasan, a commercial refrigeration manufacturer, is the leading brand in the Turkish market for beverage exhibitors. Klimasan product portfolio includes supplying hydrocarbon-based refrigerators, coolers and storage cabinets. The company’s customers include main beverage producers in Europe and the Middle East, such as Coca-Cola and Heineken. ¹⁰⁵
Knudsen Koling	Denmark	Manufacturer and developer of complete refrigeration solutions for supermarkets. By 2010 the company had installed over 70 transcritical CO ₂ boosters systems in Denmark. ¹⁰⁶
Koxka (part of Ingersoll Rand companies)	Global	Koxka has outlets in North and South America, Europe, Asia, south East Asia. In 2009, the company launched a line of CO ₂ -compatible island display cabinets in supermarkets. The company is also developing CO ₂ -based refrigeration systems. ¹⁰⁷
Kuvatek	Denmark	Produces hydrocarbon-based tap water coolers and beer coolers. ¹⁰⁸

¹⁰¹ <http://www.hydrocarbons21.com/content/articles/2009-06-02-husky-to-launch-r290-cabinet.php>

¹⁰² www.hydrocarbons21.com 2009-10-07

¹⁰³ <http://www.hydrocarbons21.com/news/view/3164>

¹⁰⁴ Johnson Controls: “Refrigerant Choices for the Future”: 2012.

¹⁰⁵ <http://www.klimasan.com.tr/2010/Default.aspx>

¹⁰⁶ <http://www.r744.com/articles/2010-07-01-coming-soon-knudsen-koling-s-transcritical-co2-compressor-pack-systems-.php>

¹⁰⁷ www.r744.com 2009-09-04

¹⁰⁸ TemaNord. 2007: “Potent Greenhouse Gases: Ways of Reducing Consumption and Emission of HFCs, PFCs 7 SF6”: report prepared for the Nordic Council of Ministers p. 29

Table 5, cont'd

Company	Country	Equipment Details
Luvata	Italy	Luvata produces CO ₂ evaporators designed for small workrooms and cold-rooms used for fresh food preservation. ¹⁰⁹ The company also plans to produce CO ₂ evaporators for vending machines and bottle coolers.
Maja	Germany	Maja, provides ice making units for supermarkets throughout Europe. The company offers product line options for ice machines running completely on natural refrigerants. The technology employs a combination of ammonia and CO ₂ as the system refrigerants. These units are becoming a preferred choice of supermarket chains for integrating existing or planned centralized CO ₂ refrigeration systems with an ice making capacity. ¹¹⁰
Manitowoc Food Services	United States	In May 2012, the Wisconsin company, Manitowoc launched its R290-based "Indigo" ice machine. The product will first be marketed in Europe, Australia and South Africa. The company projects 20-30% energy savings over comparable HFC-404a units. ¹¹¹
M & M Refrigeration	USA	M&M Refrigeration, based in Maryland, USA, is a worldwide supplier of industrial refrigeration systems and controls. The company produces ammonia/CO ₂ cascade refrigeration systems for cold storage warehouses, industrial blast freezing and food processing. M&M has installed several ammonia/CO ₂ cascade systems in the US as well as other countries and reports a steady growth in market interest in the system. Significant energy savings are reported with the ammonia/CO ₂ cascade systems compared to similar conventional ammonia systems. M&M also install ammonia/calcium chloride systems for ice rinks. ¹¹²
Palfridge	Swaziland	In 2010, Palfridge, with the support of GIZ ProKlima, has converted the refrigerants in all of its production line to hydrocarbons. Currently (2012), the company is in the process of converting all of its insulation technology to hydrocarbons with the support of the Multilateral Fund of the Montreal Protocol and the UNDP.
Sanyo Electric (Panasonic)	Japan/Global	Sanyo sells hydrocarbon domestic refrigerators and CO ₂ commercial refrigerators. The company also sells CO ₂ showcases and heat pumps, and CO ₂ compressors for vending machines. The company reports that since 2005 almost all beverage companies in Japan are purchasing some of their vending machines with natural refrigerants (either CO ₂ or HC). There are over 60,000 CO ₂ vending machines in the Japanese market today. Sanyo also produces compressors for "hot and cold" CO ₂ vending machines that provide both hot and cold beverages in one machine. As well, the company produces CO ₂ heat pumps and water heaters under the label "EcoCute." Industry-wide, EcoCute has a market volume of over 1 million units since 2001. It is reported that up to 500,000 EcoCute units are produced annually, representing the largest market for CO ₂ refrigerants in the world. ¹¹³

¹⁰⁹ <http://www.r744.com/articles/150120111020.php>

¹¹⁰ http://www.maja.de/dp_content.php?item=535_12545

¹¹¹ <http://www.hydrocarbons21.com/news/view/3164>

¹¹² Greenpeace correspondence with M&M Refrigeration, April 2012.

¹¹³ UNEP DTIE OzonAction : HCFC Help Centre : www.unep.fr/ozonaction/topics/hcfc_case-studies.htm : "CO₂ Vending Machines " by Sanyo Electric Co. Ltd

Table 5, cont'd

Company	Country	Equipment Details
Staycold	South Africa, Australia and the United Kingdom	Staycold's "Green Sense Plus" range of products features chillers and coolers that use cyclopentane foam for the insulation and R600a as the refrigerant. These units are fully functional at high temperatures and humidity (up to 40°C and 77% humidity). Energy efficient glass doors and LED lighting, along with the natural refrigerants, give an energy reduction of up to 69% over comparable HFC-134a products, depending on unit size. ¹¹⁴
Trox Aitcs Ltd.	United Kingdom	Trox Advanced IT Cooling Solutions (AITCS) produces and installs CO ₂ based data center cooling solutions. "As a heat absorption device, the system removes the PC heat at source, reducing background room cooling to a minimum. The use of 'non-water' liquid CO ₂ eliminates the potential hazards of mixing water and electronics." ¹¹⁵ Per kilogram, CO ₂ has seven times the cooling capacity of water, so the volume flows with smaller diameter distribution pipework is reduced. ¹¹⁶
True Manufacturing	United States	True Manufacturing is a global commercial refrigeration manufacturer that supplies the foodservice, hospitality, QSR, institution, beverage, and retail industries. The company currently offers self-contained refrigerators and freezers with less than a 150-gram charge of R290 to foodservice and beverage customers throughout the EU. True Manufacturing is also offering select glass door merchandisers (display cabinets) to key retailers throughout the USA. The company strategy is to continue to offer R290 solutions in their range of equipment that is able to hold up to the rigorous performance standards of their customers throughout all markets. True's line of Natural Refrigerant units consume up to 15% less energy than standard HFC systems. ¹¹⁷
UBC Group	Ukraine	A manufacturer of hydrocarbon bottle coolers and cooler cabinets. Customers include Heineken and Pepsi, with products being sold in the European and Russian markets. Approximately 30% of UBC's products now use hydrocarbons. ¹¹⁸
United States Cold Storage	United States	United States Cold Storage is pioneering a new CO ₂ refrigeration technology used in food storage facilities in Indiana, California, Pennsylvania, and Florida. ¹¹⁹ The system uses ammonia and CO ₂ in a cascade system that allows for lower operating pressures and confines ammonia to the machine room only.
Verco	United Kingdom	Producer of commercial hydrocarbon based display cabinets, including open chill, plug-in and glass door cabinet ranges. The company reports 15–20% energy savings. ¹²⁰

¹¹⁴ <http://www.greensenseplus.com.au>

¹¹⁵ <http://www.troxaitcs.com/aitcs/products/CO2OLdesk/index.html>

¹¹⁶ <http://www.r744.com/articles/2009-04-29-why/co2-data-centre-cooling-is-gaining-favour.php>

¹¹⁷ Greenpeace correspondence with True Manufacturing, April 2012.

¹¹⁸ <http://www.hydrocarbons21.com/news/view/3164>

¹¹⁹ http://www.uscoldstorage.com/newsletter/pdf/IN_March2009.pdf, Press Release "United States Cold Storage Scheduled to Open First Facility in Indiana" March 16, 2009.

¹²⁰ www.ver.co.uk/

Table 5, cont'd

Company	Country	Equipment Details																														
Vestfrost Solutions	Denmark	The large Danish cooling equipment manufacturer has a vast array of commercial equipment using natural refrigerants. The majority of the company's products are available with hydrocarbons (R-600a and hydrocarbon blends), with "more to come."																														
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Williams Refrigeration	United Kingdom, China and Australia	<p>Williams Refrigeration offers a line of hydrocarbon (R290) cabinets for the food service and bakery industry. The product contains 100 g of propane, and with the use of "Cool Smart" intelligent controllers and self-closing doors can realize energy savings of up to 15%.¹²¹</p> <p>The hydrocarbon range is designed to operate efficiently and effectively in the harshest of environments up to 43°C ambient, Climate Class 5. Their hydrocarbon cabinets are available at no extra cost across the entire range of cabinets and counters.</p>																														

¹²¹ http://www.williams-refrigeration.com/Sitelmages/Site_321/Pdf/WHyd_0609.pdf

C.3 Industrial use of ammonia in cooling applications

Ammonia is widely used in a variety of industrial cooling applications. Specifically in the foods industry, ammonia is used in various processes for cooling purposes. Europe is in the forefront of using ammonia in industrial processes. Furthermore, facilities are able to use ammonia for industrial processes as well as space cooling.

C.3.a Industrial applications of ammonia in refrigeration and freezing

Table 6: Examples of recent developments in ammonia technology and industrial applications of ammonia in refrigeration and freezing¹²²

Company	Notes
Axima Refrigeration GDF Suez ¹²³	<p><u>Belgian Icecream Group (BIG)</u></p> <p>Axima Refrigeration has developed an advanced ammonia cooling system for the Belgian Icecream Group (BIG). BIG, as an ice cream manufacturer, is part of an industry that relies on superior cooling. Following pasteurization and homogenization, a mixture of cream, sugar and other ingredients is frozen and beaten up to ice cream in continuous freezers. The finished products, from cones and desserts to sorbets are sent to ducts for ultra fast freezing, after which they are packed. They are then placed in freezer storage (over 90000 m²) at a constant temperature of -30°C. Axima Refrigeration was the first in Belgium to use a Powerdrive frequency converter with a permanent magnet synchronous motor during the installation of a new screw compressor at BIG, giving 10% better energy efficiency.</p>
	<p><u>Coca-Cola Belgium & Luxembourg</u></p> <p>Axima Refrigeration carried out an energy audit for the Coca-Cola Company, which included a measurement campaign, a technical inspection and an extensive report. This resulted in energy saving solutions such as frequency controlled compressors and fans that save Coca-Cola roughly 25% in energy consumption. Moreover, thanks to an optimal display control system, Coca-Cola can adapt the cold production to the demand. And by mapping the different temperature levels and energy flows, they can work at a higher global efficiency. The new refrigeration system installed for their Belgium and Luxembourg distribution center is ammonia-based and is a flooded-glycol pump circulation system with a capacity of 4000 kW.</p>
	<p><u>Colruyt</u></p> <p>Colruyt is a supermarket chain in Belgium with over 215 stores. For the new warehouses at Dassenveld in Halle, Axima Refrigeration built a refrigeration unit (ammonia/glycol) for various temperatures. Axima Refrigeration also installed a new ammonia-based and eco-friendly central refrigeration unit for Vlevico, Colruyt's renewed meat plant. The plant reduced its CO₂ emission by 1602 tons, saving 371 000 Euros each year in energy costs. The heat released from the refrigeration unit is recaptured for the production of hot water. BESS study (Benchmarking and Energy management Schemes in SMEs) declared Vlevico one of the most efficient and ecological meat processing companies in Europe.</p>
	<p><u>Danone</u></p> <p>Danone, the French dairy giant, operates a plant for manufacturing yogurt and cottage cheese in Fèrrières en Bray, Northern France. The refrigeration system consists of liquid chilling units using ammonia, which supplies 400 m³/h of chilled water at 1°C. The chilled water is conducted to various consumers like cold stores and specific rooms through a piping network. As the demand for cold energy varies over the day, Axima Refrigeration supplied an ice storage tank that stores the extra cold energy and releases it again when demand is high.</p>

¹²² Some examples provided by eurammon, the European initiative for natural refrigerants, www.eurammon.com/

¹²³ <http://www.aximaref-gdfsuez.be/en/customer-stories>

Table 6, cont'd

Company	Notes
Axima Refrigeration GDF Suez ¹²⁴	<p><u>Danone</u></p> <p>Danone has relied on Axima Refrigeration as its refrigeration specialist, outside of France as well, for many years. In 2000, Axima has set-up an installation for a 8000 m² Danone production plant and distribution center in Rotselaar, Belgium. Throughout each phase of the production process, refrigeration is of the utmost importance: from the storage of the milk, the preparation of the drinks and the fruit to the bottling. There may not be a single interruption in the cold chain. The central unit using ammonia has a total capacity of 7 MW, controlling 3 different temperature levels throughout the plant.</p>
	<p><u>Drillieux</u></p> <p>Drillieux is a Belgian fruit distributor. In 2011, Axima Refrigeration built for Drillieux eighteen new cold rooms with Ultra Low Oxygen (ULO) storage, with a total storage capacity of 5 million kilos. ULO means balancing the amount of oxygen, CO₂ and the temperature, in order to shut down the ageing process. This allows for apples and pears to be stored during a whole year. Axima Refrigeration expanded the existing cooling system with NH₃ as the sole refrigerant. Three new frequency controlled piston compressors were installed, lowering the energy consumption. Moreover, the sorting floor is heated thanks to the recuperation of the heat generated by the cooling system. Axima Refrigeration was responsible for the expansion of the system, installing new pipes and building the cold rooms.</p>
	<p><u>Neste Oil</u></p> <p>Neste Oil is the Finnish national oil refinery. In Beringen, Belgium the company established a refinery for poly-alpha-olefins (a lubricant made from synthetic oils) with a daily production capacity of 270 tons of oil. Axima Refrigeration replaced a R22 refrigeration unit with a NH₃ refrigeration unit. In the first phase of the conversion, Axima Refrigeration installed an 'economizer' to save energy; fitting an air cooled condenser and an evaporative condenser in a parallel circuit, controlled by an intelligent system. In the second phase, Axima replaced the R22 refrigeration unit with a NH₃ unit, equipped with a frequency regulator and a system to reduce the condensation temperature. The whole project saves Neste Oil roughly 42 000 Euros each year in energy costs.</p>
	<p><u>Sea-Invest - Belgian New Fruit Wharf</u></p> <p>In the ports of Antwerp and Zeebrugge, the Belgian New Fruit Wharf (BNFW) processes approximately 3 million tons of fruit, making them the biggest global player in the overseas distribution of fruit. Axima Refrigeration designed the refrigeration unit (ammonia) for BNFW's brand new and fully automated shipping area. Using an NH₃ refrigerant system, the shipping area, which measures up to 32 meters high, is kept at a constant temperature year-round and at a lower energy cost.</p>
	<p><u>Verbist</u></p> <p>Verbist owns several cattle breeding farms throughout Belgium and provides high-quality beef production. Every week, roughly 600 to 700 cattle are slaughtered in Izegem, Belgium and it is important that the cold chain is never interrupted during every step of the production. Axima Refrigeration designed a NH₃ refrigeration unit with direct expansion (600 kW at -10°C). This system transfers liquid ammonia to the evaporators in the cold rooms. Inside the evaporator, the NH₃ dissipates completely. Since there is no liquid separator, the compressor sucks in the vapors directly. The expansion valves are controlled by in-house developed software and ensure a meticulous distribution of the refrigerant, avoiding liquid slugging. Axima Refrigeration installed some 40 DX evaporators at Verbist: a unique concept in Europe. The advantages over a pump circulation system are the limited amount of refrigerant (as low as 25%) and the fact that there are no pumps or separators to install leading to less safety risks and a lower investment cost.</p>

¹²⁴ <http://www.aximaref-gdfsuez.be/en/customer-stories>

Table 6, cont'd

Company	Notes
Grasso GmbH	<p>Grasso GmbH spiral chiller with finless evaporator for food freezers: Usually, heat transmitters have fins that increase the evaporator's surface. However, this also facilitates the deposition of microorganisms and makes the facility harder to clean. Thus, there is demand for finless alternatives offering the same level of efficiency in the foods industry. The heart of the prototype is a spiral chiller equipped with a finless evaporator. The evaporator is tested by cooling 8,000 regular ice packs from ambient temperature to -37°C in 30 minutes. The refrigeration energy is furnished by an ammonia/CO₂ cascade: ammonia for the high-temperature cycle, CO₂ for the low-temperature cycle. The advantage is that only 40 kg of ammonia is used, and it remains confined to the central machine room, while the freezer is supplied with CO₂.</p>
Johnson Control Systems (York Refrigeration)	<p><u>Edeka</u></p> <p>Edeka meat processing plant in Germany required a system consisting of refrigeration and deep-freeze rooms that would meet all technical requirements while remaining efficient and inexpensive. Johnson Controls Systems implemented a two-stage ammonia system involving screw compressors. It produces refrigeration output of 5,500 kW with a refrigerant charge of 10,000 kg. The cooling fluid piped through the processing rooms is ethylene glycol.</p>
	<p><u>Bayer</u></p> <p>The Bayer chemicals group commissioned York to build an ammonia-based refrigeration system at its primary plant in Leverkusen, Germany, where in one of the largest production facilities in the world, in roughly 600 buildings scattered on more than one square mile, Bayer manufactures pharmaceuticals, dyes, rubber, polyurethanes and organic and inorganic products.</p> <p>The company chose ammonia because it is an efficient, economical and environmentally friendly refrigerant. The job was part of Bayer's extension of the remote cooling system. The heat generated by all production-related processes is dissipated through a remote refrigeration plant with several refrigeration centers. Three different temperature levels are available for this process: 23, -4 and -49°F (-5, -20 and -45°C). Decentralized cascade chillers, also hooked up to the main supply, provide temperatures of -49°F and below. Bayer uses the remote refrigeration plant, which comprises several large units, to economically generate cooling energy and ensure a steady supply.</p> <p>In the York engineered refrigeration plant, two rotary screw compressor units provide cooling energy. The refrigerant, ammonia, is liquefied in condensers that are supplied with cooling water. The refrigerant is then fed into the liquid line through a sub-cooler and part-time jetting pumps as needed to supply the process loads. The overheated ammonia gas returned by the network is cooled in a suction separator and is then returned to the suction side of the compressor. The plant's refrigeration output exceeds 5 MW.¹²⁵</p>
Kältetechnik Dresden + Bremen	<p><u>German Poultry Producer</u></p> <p>The new production facilities of a German poultry producer, with a total floor space of approximately 5,000 m², were to be equipped with a number of different refrigeration and processing rooms. The spectrum of required temperatures extended from -30°C to 7°C. Kältetechnik Dresden + Bremen built a three-stage ammonia refrigeration plant with a glycol cycle. Four screw compressors and one piston compressor were used to control the various temperature level requirements of the system, which was charged with 2,850 kg of ammonia. The deep-freeze warehouse and the shock-freeze rooms with a refrigeration output of 410 kW at -40°C are directly supplied with ammonia. An ethylene glycol cycle with a flow temperature of -12°C cools the production rooms (e.g. filleting, fresh storage, and packaging rooms), and an integrated ventilation system with a total refrigeration output of 2,190 kW. In a spray-humidified chilling tunnel that is also linked into the cycle, roughly 9,000 chickens per hour are cooled down to a temperature of 2°C.</p>
	<p><u>German Confectionery Manufacturer</u></p> <p>A leading German confectionery manufacturer erected a new production building in Halle/Westphalia, Germany. Here Dresden + Bremen installed an ammonia based refrigerating plant for process refrigeration and air-conditioning. Process refrigeration is responsible for controlled heat removal during the production of chocolate, sweets, and fruit gums, and for cooling the machines. The focal element of the central plant consists of four frequency-controlled screw compressors. The consumers are supplied with refrigeration via two liquid circuits at temperatures between 5°C and 11°C. The process refrigeration circuit uses cold water, while the air-conditioning system works with a propylene glycol circuit.</p>

¹²⁵ http://www.process-cooling.com/Articles/Feature_Article/71ec9c7773a5c010VgnVCM100000f932a8c0

Table 6, cont'd

Company	Notes
KWN Engineering-Gesellschaft	<p><u>Zipf Brewert</u></p> <p>The Zipf Brewery in Austria, a Brau Union Österreich AG brand, relies on an ammonia plant with slurry ice as coolant for its refrigeration needs. The retrofit was realized by the Austrian company, KWN Engineering GmbH. The existing refrigeration system was kept, but the coolant cycle as well as part of the ammonia pump system was replaced with slurry ice—a mix of ice, refrigerants, and anti-corrosives. Most of the existing pipelines were kept, as were the heat exchangers on the beer tanks and in the refrigeration rooms. New installations included two 230-kW ice generators and air coolers supplied by Güntner. A 110-m³ silo with a refrigeration capacity of 2,800 kW was added to serve as an ice bank.</p> <p><u>Recheis Teigwaren GmbH</u></p> <p>The Austrian market leader Recheis Teigwaren GmbH required conditioned storehouses, regular and deep-freeze storehouses, and a combined spiral/freezer-cooler for the manufacturing of filled fresh and frozen pastas, and to store the raw materials that go into them. The company required an economical and environmentally friendly refrigeration facility that complies with Austria's F-Gases regulation. To furnish all of the cold energy demands without using HFCs, the KWN Engineering-Gesellschaft mbH designed a refrigeration facility using ammonia. A CO₂ cascade was additionally installed for the deep-freeze storehouse and the spiral freezer and cooler.</p>
Nestlé	<p>The global food producer, Nestlé, has pioneered ammonia-CO₂ cascade systems in varied applications, including: (a) building in 2000 the largest CO₂-ammonia cascade system “built in the past 50 years” at its Nescafé factory in Hayes, England, because no commercial scraped-surface heat exchange system was available for freezing coffee liquor; (b) commissioning in 2003 “one of the first and world's largest” ammonia-CO₂ systems at Nestlé USA's prepared meals plant in Jonesboro, Arkansas; and (c) commissioning in 2005 the worlds first CO₂ ice cream freezer plant in Thailand ahead of the 2030 HCFCs phase out schedule of the Montreal Protocol. The company sources technology from across the globe, and at times co-designs them when they are not available.¹²⁶</p>
Roche	<p>The giant Swiss healthcare company, in a commitment to rid itself by 2015 of chemicals that harm the ozone layer or cause global warming, is installing ammonia cooling in its new facilities in Germany, Ireland and the United States. At Roche's Indianapolis facilities fluorocarbon chillers are in the process of being replaced with ammonia in the facility's 16,000 m² chiller plant building. In Ireland, a similar replacement reduces Roche's CO₂ emission by 575 tons annually. In Germany, the company is using a mixture of ammonia, propane, and CO₂.</p>
Star Refrigeration	<p><u>ASDA</u></p> <p>Beginning in 2002, the British supermarket chain ASDA had Star Refrigeration replace all refrigeration units that use the hydrochlorofluorocarbon (HCFC) R22 at its distribution centers, as part of a long-term modernization program. Star Refrigeration designed an ammonia/CO₂ cascade system.</p> <p>At one of ASDA's major distribution centers in Lutterworth, UK the refrigeration system provides efficient refrigeration for the 270,000m³ premises. Areas requiring refrigeration are: a frozen food cold store at -25°C and several chill rooms at temperatures between 1°C and 13°C. The chill rooms are cooled with carbon dioxide as a volatile secondary refrigerant.¹²⁷</p>

¹²⁶ <http://www.foodprocessing.com/articles/2009/074.html>

¹²⁷ <http://www.eurammon.com/englisch/html/natuerlich/fallstudien/asda.htm>

Table 6, cont'd

Company	Notes
Star Refrigeration	<p><u>Lundbeck Pharmaceuticals</u></p> <p>Lundbeck Pharmaceuticals, a Danish drug manufacturer, needed to expand its production capacity in Seal Sands, England. The production process requires adhering to precisely specified temperature gradients, with temperatures ranging from -121 to 500°F (-85 to 260°C). Lundbeck required a cooling solution that was efficient, reliable and environmentally friendly.</p> <p>Star Refrigeration produced two factory-built, skid-mounted air-cooled ammonia systems that supplied each loop with cooling energy. Factory packaging significantly reduced onsite assembly and facilitated the production start-up. The low-temperature cycle at 41°F (5°C) cools 400 m³/hr of the coolant Therminol D12 from Solutia with a refrigeration output of 1.4 MW.</p> <p>The ultra-low temperature cycle chills 50 m³/hr of Therminol D12 to -13°F (-25°C) with an output of 220 kW. Both cycles use soundproof rotary screw compressors and high-performance fully welded plate and shell evaporators, which assist in the design of a system with a small refrigerant charge. The refrigeration systems have tanks for storing the secondary refrigerant, which helps to bridge downtimes and facilitate maintenance work. Star Refrigeration equipped the plant with modern controls, including ammonia detectors. Thanks to the modular design, the operator can easily and inexpensively expand the installation at any time.¹²⁸</p>
	<p><u>Guinness Brewery</u></p> <p>Guinness Brewery in Dublin planned to increase its production volume of Guinness Stout beer to twelve million barrels per year. Star Refrigeration extended the 5 MW system up to 8.9 MW, which complements the existing facilities perfectly. The refrigeration specialists installed six additional variable-speed-drive glycol pumps and increased the condenser capacity. The modernised system now has a refrigeration capacity of 8.9 MW at an evaporating temperature of -4.5°C, without noticeably increasing the ammonia refrigerant charge in the system.</p>
	<p>Star Refrigeration has a range of ammonia cooling solutions under the Azanefreezer line. The Azanefreezer is a complete refrigeration package specifically designed for temperature controlled storage facilities.</p> <p>The benefits of the system include: no plant-room requirement, low installation costs, no affluent water needs and, notably, a low ammonia charge of 1.5 kg/KW. The Azanefreezer is available in a range of modules, from 110kW to 250 kW for a nominal cold storage temperature of -25°C.¹²⁹</p>

C.3.b Use of ammonia in food distribution centers

Ammonia is a highly efficient refrigerant. It is widely used globally in large facilities such food distribution centers.

Table 7: Examples of ammonia in food distribution centers

Company	Country	Notes
ASDA	United Kingdom	<p>As part of a long-term modernization program, beginning in 2002, the British supermarket chain ASDA had Star Refrigeration replace at its distribution centers all refrigeration units that used (HCFC) R22 with ammonia. Star Refrigeration designed an ammonia/CO₂ cascade system.</p> <p>At one of ASDA's major distribution centers in Lutterworth, UK the refrigeration system provides efficient refrigeration for the 270,000m³ premises. Areas requiring refrigeration are: a frozen food cold store at -25°C and several chill rooms at temperatures between 1°C and 13°C. The chill rooms are cooled with carbon dioxide as a volatile secondary refrigerant.¹³⁰</p>
Coca-Cola Company	Europe	<p>Axima Refrigeration of Europe installed various energy saving measures for Coca-Cola, resulting in an overall energy reduction of 25%. The new refrigeration system installed for Coca-Cola's Belgium and Luxembourg distribution center is ammonia-based, flooded-glycol pump circulation system with a capacity of 4000 kW.¹³¹</p>

¹²⁸ <http://www.eurammon.com/englisch/html/natuerlich/fallstudien/lundbeck.htm>

¹²⁹ <http://www.star-ref.co.uk/star/air-cooled-ammonia-packaged-unitcold-storage-azanefreezer.html>

¹³⁰ <http://www.eurammon.com/englisch/html/natuerlich/fallstudien/asda.htm>

¹³¹ <http://www.aximaref-gdfsuez.be/en/customer-stories/industrial-refrigeration/food/breweries-and-soft-drinks>

Table 7, cont'd

Company	Country	Notes
Delhaize Group	Belgium	<p>In 2009, the Belgian supermarket chain Delhaize expanded its existing distribution center in Zellik, Belgium with an additional 150,000m³ of loading and unloading bays and a warehouse.</p> <p>The new building consists of an automated warehouse with loading and unloading bays continuously refrigerated at a temperature between +1°C and +3°C. In order to make best use of the storage space, a technical corridor had to be installed above it to accommodate the refrigeration installation.</p> <p>The building is refrigerated by ammonia. As the volume of ammonia had to be limited to the machine room and the condensers the system uses secondary cooling medium such as glycol or CO₂.</p> <p>Furthermore, the distribution center roof is equipped with 6,000 m² of photovoltaic cells that generate 306 MWh each year. The building is also insulated extremely well and 12,000m³ of water is recuperated in a reservoir each year.¹³²</p>
Fresh & Easy Neighborhood Markets (Tesco USA)	United States	<p>In 2008, Fresh & Easy opened its Riverside Distribution Center (Riverside, California), which is a 53,000 sq-ft building that serves as the meat and poultry processing and distribution center for their grocery stores in California. The two-stage pumped re-circulated ammonia system serves a multitude of 30-40°F processing rooms, (2) -30°F spiral blast freezers, and other processing equipment via 53 evaporators, (2) make-up air units, and 1,500 horsepower of screw compressors.</p> <p>The building has a state-of-the-art Refrigeration Control System with remote monitoring capabilities, ammonia detection controls, refrigeration and defrost controls, and energy efficiency optimization strategies.¹³³</p>
Giant Food Stores (Ahold USA)	United States	<p>The Giant Distribution Center in Carlisle, PA is food distribution facility, which operates on a two-temperature, single stage, anhydrous ammonia (R-717) refrigeration system. This refrigeration system is a liquid re-circulation system. Rotary screw and reciprocating compressors are used in the refrigeration system.</p> <p>This facility was expanded to its current size in November 1999. In 2006, 4 additional banana rooms were added to the facility. The new banana rooms tie into the system and require the addition of 700 pounds of ammonia to maintain the manufacturers recommended safe operating pressure; it has a total inventory of approximately 26,903 pounds of anhydrous ammonia in its refrigeration system.¹³⁴</p>
Lidl	Germany	<p>In 2010, the German retailer, which is part of the Schwarz Group, opened a new, 33,200 sq-meter, distribution center in Paderbom, Germany. The center uses CO₂ and ammonia for low and medium temperature cooling.¹³⁵</p>

¹³² http://www.johnsoncontrols.com/content/dam/WWW/jci/be/eu_library/energy_solutions/Case_Study_DELHAIZE_ZELLIK_ENG.pdf

¹³³ <http://www.clrefrigeration.com/asp/admin/getFile.asp?RID=5&TID=11&FN=PDF>

¹³⁴ http://data.rtknet.org/rmp/rmp.php?database=rmp&detail=3&datatype=T&facility_id=100000163583

¹³⁵ <http://www.r744.com/articles/2009-06-11-lidl-new-distribution-centre-using-only-natural-refrigerants.php>

Table 7, cont'd

Company	Country	Notes
Sobey's	Canada	<p>In 2008, Sobey's opened a 13,650 square-meter refrigerated distribution center in Trois-Rivières, Québec. As the first refrigerated distribution center in Canada to be built to LEED® standards, it was nominated in 2009 for an Award of Excellence in Architecture by Ordre des Architectes du Québec. The facility has since received gold level LEED® certification.</p> <p>The distribution center contains many unique and industry-leading design features. A few of the most important features relating to cooling and refrigeration are:</p> <ul style="list-style-type: none"> • A refrigeration system that uses 33% less refrigerant than conventional refrigeration systems. Heat from the refrigeration system is used to warm the office spaces in the winter. • When determining the size of refrigeration system required for the facility, refrigeration calculations took into account the in-coming temperature of the product to be stored at the facility. The result was a smaller more energy efficient refrigeration system that leverages the products' thermal mass to maintain the right building temperature. • Ammonia coolant is used in the mechanical room, while glycol refrigerant circulates in the plant. In the event of a mechanical room ammonia leak, the ammonia can be vented without contributing to global warming. <p>The combined effect of these features resulted in energy demands that were 55% less than a similarly sized refrigerated distribution center in Québec.¹³⁶</p>
Stop & Shop (Ahold USA)	United States	<p>The North Haven Distribution Center (North Haven, CT) is a facility consisting of a 500,000 sq-ft grocery warehouse and a 265,000 sq-ft meat warehouse. The North Haven Distribution Center is one of two refrigerated facilities utilized by Stop & Shop for the storage and distribution of products to almost 200 stores. Since many of these products must remain refrigerated, Stop & Shop operates a refrigeration system using anhydrous ammonia as the refrigerant. The Stop & Shop refrigeration system operates in a sequential mode based on the heat load.</p> <p>The heat load is determined by the material being moved into the warehouse and by the outside air temperature. As such, the process control parameters of greatest consequences are the temperature and pressure readings throughout the system.¹³⁷</p> <p>The Readville Distribution Center (Readville, MA) is a facility, which consists of a 400,000 sq-ft grocery warehouse, a 200,000 sq-ft produce warehouse and a 100,000 sq-ft dairy commissary. It is one of two refrigerated facilities utilized by Stop & Shop for the storage and distribution of products to almost 200 stores. Since many of these products must remain refrigerated, Stop & Shop operates a single-stage refrigeration system using anhydrous ammonia as the refrigerant.¹³⁸</p>

¹³⁶ http://www.sobeyscorporate.com/sustainability/distribution/case_study_trois_rivieres.html and Greenpeace correspondence, August 2011.

¹³⁷ <http://www.toxicrisk.com/reports/8883/source.htm>

¹³⁸ http://data.rtknet.org/rmp/rmp.php?database=rmp&detail=3&datatype=T&facility_id=1000011737

Table 7, cont'd

Company	Country	Notes
Target	United States	In 2002, Target constructed an automated dry goods warehouse/distribution center for in Cedar Falls, Iowa. After and extensive site search, Target chose to build immediately adjacent to the original facility, thus creating a distribution campus rather than a center. Completed in June 2009, this 430,000 sq-ft automated food distribution center features 400,000 square feet of cold storage cooled by a state-of-the-art ammonia refrigeration system. ¹³⁹
Tesco Lotus	Thailand	In 2011, Tesco Lotus opened its first fresh-food distribution center in Thailand running completely on ammonia as a refrigerant. Along with other energy saving measures, the new distribution center enables up to 32% savings of carbon emissions per square meter (approximately 1,600 tonnes of carbon emissions per year). It can handle more than 230,000 cases of fresh food per day from more than 450 vendors to serve its 34 million customers each month in more than 700 stores around the country. Tesco Lotus plans on applying these “green concept” measures to the other distribution centers it operates in Thailand. ¹⁴⁰

¹³⁹ <http://www.ryancompanies.com/projects/target-food-distribution-center-ia/pager/>

¹⁴⁰ <http://www.nationmultimedia.com/home/Tesco-Lotus-opens-modern-fresh-distribution-centre-30147184.html>

D. DOMESTIC AND COMMERCIAL AIR-CONDITIONING

There is an immediate need for environmentally sustainable domestic and commercial air-conditioning technology. Demand in this cooling sector is exponentially growing in both industrialized and developing countries as we experience ever-increasing temperatures around the world because of global warming.

The global inventory of stationary air-conditioners is approximately 790 million units. This includes window and portable air-conditioners, single split type air-conditioners, multi-split type air-conditioners, ducted systems, small chillers, large chillers and centrifugal chillers. The global annual production of new stationary air-conditioning units, including all of the above A/C subtypes, is approximately 87.5 million (see **Appendix I.4** for estimates on the global production of each air-conditioner type).¹⁴¹

There are natural refrigerant alternatives to HFCs for each of these A/C subtypes, some of which are currently undergoing tremendous developments. These include, in varying applications and configurations, hydrocarbons (propane R290 and propylene R1270), carbon dioxide, ammonia, water vapor (R-718). For example, hydrocarbon split air-conditioning in domestic use is set to make major inroads, in the immediate future, in both China and India, where top manufacturers have launched hydrocarbon production lines. China's HCFC Phase-out Management Plan, under the Montreal Protocol, plans for 18 HCFC-22 air-conditioner production lines, with an annual output of 4.5 million units, to be converted to R290 by the end of 2015.¹⁴² For split air-conditioners with cooling capacity of up to about 7 kW, hydrocarbons (R290 or R1270) can be widely used in wall and ceiling A/C units. A comparison of hydrocarbon charge sizes with the standard flammability limits indicates that hydrocarbons in split air-conditioners can be used in about 65% of the cases where HCFC/HFCs are currently used.¹⁴³

Furthermore, there are numerous supermarkets, office buildings, public institutions, and other commercial enterprises in various countries that have installed HCFC/HFC-free cooling technologies using natural refrigerants. Natural refrigerant-based air-conditioning include carbon dioxide-based coolers, hydrocarbon primary systems, hydrocarbon- or ammonia-based secondary cooling systems, desiccant cooling, evaporative cooling, and absorption cooling. Consumers of cooling technologies must ensure that they chose the best available solution for their specific needs.

D.1 Manufacturers and distributors of domestic and commercial air-conditioning equipment using natural refrigerants

Table 8: Manufacturers of air-conditioning and heat pump equipment using natural refrigerants

Company	Country	Equipment Detail																																									
Benson Air-Conditioning	Australia	<p>Benson Air-Conditioning markets a variety of domestic and commercial hydrocarbon air-conditioners that are manufactured in China and Thailand. These include chillers, ducted systems, multi-head systems, rooftop packages, under ceiling systems and wall-mounted systems. According to the company, the hydrocarbon units perform with 15-20% better energy efficiency than the company's comparable previous R22 range.¹⁴⁴</p> <p>Examples of Benson models with the following heating/cooling capacity and Energy Star Ratings under Australia's MEPS scheme:</p> <table border="1"> <thead> <tr> <th>Type</th> <th>kW/Cooling Size</th> <th>Energy Star Rating</th> <th>Hydrocarbon Charge</th> </tr> </thead> <tbody> <tr> <td rowspan="5">Wall-Mounted Split Systems</td> <td>2.31/2.6</td> <td>4.5/5.5</td> <td>300 g</td> </tr> <tr> <td>3.4/3.4</td> <td>4.5/4.5</td> <td></td> </tr> <tr> <td>5.1/5.6</td> <td>4/3.5</td> <td></td> </tr> <tr> <td>6.3/6.6</td> <td>4/4</td> <td></td> </tr> <tr> <td>8.2/8.4</td> <td>4/3</td> <td></td> </tr> <tr> <td colspan="4">Ducted Systems</td> </tr> <tr> <td rowspan="3">Single Phase</td> <td>10.3/10.4</td> <td>3/3.5</td> <td></td> </tr> <tr> <td>12.3/12.1</td> <td>5/4.5</td> <td></td> </tr> <tr> <td>16.3/16.2</td> <td>3.5/4</td> <td></td> </tr> <tr> <td rowspan="2">Three phases</td> <td>12.8/12.8</td> <td>4.5/4.5</td> <td></td> </tr> <tr> <td>17.5/17.1</td> <td>4/5</td> <td>1.2 kg</td> </tr> </tbody> </table>	Type	kW/Cooling Size	Energy Star Rating	Hydrocarbon Charge	Wall-Mounted Split Systems	2.31/2.6	4.5/5.5	300 g	3.4/3.4	4.5/4.5		5.1/5.6	4/3.5		6.3/6.6	4/4		8.2/8.4	4/3		Ducted Systems				Single Phase	10.3/10.4	3/3.5		12.3/12.1	5/4.5		16.3/16.2	3.5/4		Three phases	12.8/12.8	4.5/4.5		17.5/17.1	4/5	1.2 kg
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¹⁴¹ Preparatory study for a review of Regulation (EC) (September, 2011).

No 842/2006 on certain fluorinated greenhouse gases. Annexes to the Final Report: Prepared for the European Commission in the context of Service; Contract No 070307/2009/548866/SER/C4 : pages 189 to 201.

Authors: Dr. Winfried Schwarz, Dr. André Leisewitz, Barbara Gschrey (Öko-Recherche), Anke Herold, Sabine Gores (Öko-Institut), Irene Papst, Jürgen Usinger (HEAT International GmbH), Dr. Daniel Colbourne, Prof. Dr. Michael Kauffeld, Per Henrik Pedersen and Igor Croiset.

¹⁴² <http://beta.hydrocarbons21.com/news/view/3081>

¹⁴³ Op. Cit. Preparatory study for a review of Regulation (EC) (September, 2011) p. 195.

¹⁴⁴ <http://www.bensonairconditioning.com.au/index.htm>

Table 8, cont'd

Company	Country	Equipment Detail																												
Bundgaard Køleteknik	Denmark	Producer of hydrocarbon chillers in the medium to larger range (50-400 kW), with improved energy efficiency of 10% compared to HFC chillers. ¹⁴⁵ Most installations in Denmark, with some exports to Germany, Norway and UK.																												
De'Longhi	Italy	<p>De'Longhi has been producing a range of hydrocarbon-based domestic air-conditioners in the European market since 1995. The De'Longhi range includes a variety of portable units for varying room sizes. Portable air-conditioners can be moved to cool individual rooms. De'Longhi also produces split-system wall mounted units.</p> <p>Examples of De'Longhi Products:</p> <table border="1"> <thead> <tr> <th>Type</th> <th>Refrigerant</th> <th>Cooling Capacity</th> <th>Specifications</th> </tr> </thead> <tbody> <tr> <td>Maestro CPA 30 AR-E290 Heat Pump</td> <td>Propane (R290)</td> <td>11.253 Btu/h 3.3 kW</td> <td>-low noise level (36 dB indoor, 45 dB outside), compressor outside -indoor unit weight 9 kg with size -outdoor unit weight 35 kg -remote control with three fan speeds -plugs into normal 13A socket</td> </tr> <tr> <td>Ready-to-Install Wall-Mounted Air-Conditioner</td> <td></td> <td></td> <td></td> </tr> <tr> <td>Pinguino PAC T 105 ECO</td> <td>R290</td> <td>8,000 Btu/h</td> <td>-dehumidifies while cooling, removing 25 L/day of excess moisture -electronic humidistat -two speed ventilation + quiet mode -auto fan function</td> </tr> <tr> <td>Portable Split system air conditioner</td> <td></td> <td></td> <td></td> </tr> <tr> <td>Pinguino PAC T06eco</td> <td>R290</td> <td>10,000 Btu/h</td> <td>-energy efficiency class A -dehumidifies while cooling, removing 45 L/day of excess moisture -electronic humidistat -Air Cleaning System removes particles -two speed ventilation + quiet mode</td> </tr> <tr> <td>Pinguino PAC T90 ECO</td> <td>R290</td> <td></td> <td>-energy efficiency rating A</td> </tr> </tbody> </table>	Type	Refrigerant	Cooling Capacity	Specifications	Maestro CPA 30 AR-E290 Heat Pump	Propane (R290)	11.253 Btu/h 3.3 kW	-low noise level (36 dB indoor, 45 dB outside), compressor outside -indoor unit weight 9 kg with size -outdoor unit weight 35 kg -remote control with three fan speeds -plugs into normal 13A socket	Ready-to-Install Wall-Mounted Air-Conditioner				Pinguino PAC T 105 ECO	R290	8,000 Btu/h	-dehumidifies while cooling, removing 25 L/day of excess moisture -electronic humidistat -two speed ventilation + quiet mode -auto fan function	Portable Split system air conditioner				Pinguino PAC T06eco	R290	10,000 Btu/h	-energy efficiency class A -dehumidifies while cooling, removing 45 L/day of excess moisture -electronic humidistat -Air Cleaning System removes particles -two speed ventilation + quiet mode	Pinguino PAC T90 ECO	R290		-energy efficiency rating A
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Frigadon	Sweden	<p>Frigadon has developed a range of hydrocarbon packaged air-conditioners using R1270 (propylene). The range of chillers covers capacities between 29 and 208 kW at +7OC flow temperature and 15.6 kW at -8 OC flow temperature. Low-temperature chillers of up to 88 kW at -31OC are also available. All units come with complete controls and electrics, as well as built-in hydraulic kit with inverter drive circulation pump.</p> <p>Frigadon installations can be found in the United States, Germany, United Kingdom and Ireland, with companies such as Sainsbury's, COOP Bank, British Land, Cooplands Bakery, Nestle, Dunnes Stores, Braehead Foods, BP, Roche Pharmaceuticals and Welcome Break Motorway Services.¹⁴⁶</p>																												

¹⁴⁵ Danish EPA: 2012: "Low GWP Alternatives to HFCs in Refrigeration"

¹⁴⁶ <http://www.srs-comp.com/high-efficiency-products.html>

Table 8, cont'd

Company	Country	Equipment Detail																				
Godrej & Boyce	India	<p>In 2012, Godrej & Boyce Mfg. Co. Ltd. inaugurated a new production line for the manufacturing of split and window-type propane (R290) air-conditioners. The new line is in the 1.5 T split category, which is the most common air conditioner segment in India. It is estimated that the R290 models will consume at least 23% less energy than the current top-of-line 5-star models across other brands.</p> <p>The R290 line was developed in cooperation with the German Development Agency, GIZ ProKlima. This project has drawn the interest of three other Indian manufacturers as hydrocarbon air-conditioners may achieve higher energy star ratings.¹⁴⁷</p>																				
Gree Electric Appliances	China	<p>Gree is the largest manufacturer of residential air-conditioners worldwide. In cooperation with GIZ ProKlima, Gree developed a high efficiency propane (R-290) domestic split air-conditioner with a COP of 3.52-3.55. Energy efficiency is 15% better than corresponding HCFC-22 units, and has a total hydrocarbon charge of less than 300g. In 2011, Gree officially launched its production line for the hydrocarbon air-conditioners, which will produce approximately 100,000 HC A/C units per year.¹⁴⁸</p> <p>R290 units are cheaper to produce than R22, R407C, and R410A units because R290 uses narrower tubes in the condenser and evaporator. R290 has better heat transfer properties and lower pressure drop as well. Gree R290 air-conditioners conform to all EU regulations, and the refrigerant charge is lower than required by international standards (IEC 60335-2-40). The units include a refrigerant leak alarm system that turns off the compressor, keeps fans operating, and sets off an alarm with flashing lights.</p> <table border="1"> <thead> <tr> <th>Capacity Kw (Btu)</th> <th>COP w/w</th> <th>Charge (g)</th> <th>Max noise Inside (dB)</th> <th>Max noise Outside (dB)</th> </tr> </thead> <tbody> <tr> <td>2.7 (9K)</td> <td>3.55</td> <td>265</td> <td>38</td> <td>52</td> </tr> <tr> <td>3.2 (11K)</td> <td>3.54</td> <td>310</td> <td>41</td> <td>52</td> </tr> <tr> <td>3.5 (12K)</td> <td>3.52</td> <td>330</td> <td>41</td> <td>52</td> </tr> </tbody> </table> <p>Gree also produces hydrocarbon portable air-conditioners and dehumidifiers. The company reports 10% efficiency gains with the portable A/C units and 20% efficiency gains with the dehumidifiers.¹⁴⁹</p>	Capacity Kw (Btu)	COP w/w	Charge (g)	Max noise Inside (dB)	Max noise Outside (dB)	2.7 (9K)	3.55	265	38	52	3.2 (11K)	3.54	310	41	52	3.5 (12K)	3.52	330	41	52
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Mayekawa	Japan	<p>Developed a central air-conditioning and hot water supply system using hydrocarbon zeotropic blend of isobutane and propane. The system uses air and water as the heat source and heat sink to provide cooling, heating, and hot water production.¹⁵⁰</p>																				
Recom Engineering	Australia	<p>In 2008, the company was preparing to market Chinese-produced Fujin air-conditioners with hydrocarbons in split-system commercial applications.</p>																				
Sanyo	Japan/Global	<p>Sanyo has been selling CO₂ heat pumps/water heaters in the Japanese and Nordic markets since 2001 and 2004, respectively. Sanyo has been selling CO₂ vending machines and showcases since 2004.</p>																				
York (Johnson Controls)	Denmark/Global	<p>York is producing a line of medium-sized, air-cooled hydrocarbon chillers with frequency-controlled screw compressor, and V-coil condenser. The capacity range is from 80 to 560 kW.</p>																				

¹⁴⁷ <http://www.giz.de/Themen/en/SID-A15D951A-3295E3E5/dokumente/giz2012-en-new-production-line-proklima-godrej-boyce.pdf>

¹⁴⁸ <http://www.hydrocarbons21.com/news/view/2687>

¹⁴⁹ Gree Power Point Presentation: "Application of HC Refrigerant in Package Portable Room Air Conditioners and Dehumidifiers". Presented at "Advancing Ozone and Climate Protection Technologies: Next Steps" Conference in Bangkok: July 2012.

¹⁵⁰ www.r744.com 2010-02-25

D.2 Examples of facilities cooled with air-conditioning using natural refrigerants

Hydrocarbons continue to gain market acceptance in commercial cooling applications. Hydrocarbon chillers are now available in a wide variety of sizes, with the largest being around 1,000 kW. Along with this are carbon dioxide systems that are just entering the market at a rapid pace.

Table 9: Examples of hydrocarbon and CO₂ air-conditioning in commercial and public buildings

Company	Country	Notes		
Earthcare Ltd.	UK	Earthcare has installed split-system air-conditioning using hydrocarbon refrigerants in a wide variety of settings, including the following:		
		Middlesex University	Great Ormond Street Children's Hospital -8 split systems installed	University College in London
		Pembury Hospital in Kent	Her Majesty's Customs and Excise offices	Confectionary Factory in York
		Horsham Arts Centre	Government Laboratory in Birmingham	Alverston Library in Derby
		London Transport in West Kensington	DVLA Oxford	Brighton Library
		Shropshire County Council	DEFRA Whitehall	Pharmaceutical Company in Welwyn Garden City
		Government Laboratory in Chepstow	DFT in Westminster	National Trust in Swindon
	South Downs Health Authority	Medway Health Authority		
ABN Amro	Netherlands	The Dutch bank ABN Amro uses a CO ₂ system to cool 15 high-performance servers at the data centre of its London branch. To provide a controlled climate for this hardware, the refrigeration systems manufacturer Star Refrigeration designed and built a low-energy-consumption CO ₂ refrigeration system to generate a total output of 300 kW. The carbon dioxide is recondensed with water at 6°C via an indirect chilling cycle. The cooling is handled by ventilator units on the back of the server cabinets, where the carbon dioxide evaporates at 14°C and absorbs the heat siphoned off by the fans. ¹⁵¹		
Various Other Companies	Global	Facilities equipped with hydrocarbon air-conditioning:		
		Edeka Supermarkets (Germany)	Frucor Processors (Hastings, New Zealand)	Tip Top Bread (Auckland, New Zealand)
		Kiwi Co-operative Diaries Ltd, (Hawera, New Zealand)	Bodo Airbase (Norway)	Backhammars Bruk (Sweden)
		AG-Favor (Sweden)	PUB Department Store (Sweden)	Sainsbury's Supermarkets (UK)
		Tesco Supermarkets (UK)	Out of This World Stores (UK)	Iceland Supermarkets (UK)
		National Trust (UK)	Royal Institute of British Architects (UK)	National Hospital (UK)
		Chartered Society of Physiotherapy (UK)	London Transport (UK)	Esso Gas Station Supermarkets (UK)
		Church of England (UK)	Supermarket (Germany)	McDonald's conversion (Philippines)
University Hospital: Aarhus (Denmark)	Greenpeace- Australia Offices (Australia)			

¹⁵¹ eurammon: Example provided by eurammon, the European initiative for natural refrigerants, www.eurammon.com/B

D.3 Ammonia air-conditioning

Ammonia has been used in refrigeration and air-conditioning since the 1850s. It has superior thermodynamic properties and is highly energy efficient. The most prominent example of the use of ammonia in air-conditioning is in the international space shuttle. Meanwhile, air-conditioning systems around the world, including universities, hospitals, hotels, office buildings, convention centers, and airports, also utilize ammonia.

Table 10: Examples of ammonia air-conditioning in commercial enterprises

Country	Facility	Type of Enterprise
Canada	Campbell's Soup (Toronto)	Office building
Denmark	Hvidovre Hospital	Hospital
	Copenhagen University Rigshospitalet	Hospital
	Fields Copenhagen	Shopping Mall
	Ilum Department Stores	Department store
	Magasin Department Stores	Department Store
	Aarhus Congress Center	Convention Center
	Scandic Hotel Copenhagen	Hotel
	Hotel Scandinavia Aarhus	Hotel
	SDC Bank	Data bank for financial institutions
	Copenhagen Airport	Airport
	Danish National Television	Television Studios
SAS Building (Aarhuz)	Airline Office Building	
Germany	Hannover Trade Fair Building (one of the largest commercial ammonia air-conditioning systems in the world, using 2.5 tons of ammonia to generate 3.5 MW of cooling)	Trade Fair Building
	Leipzig Trade Fair Building	Trade Fair Building
	Lindplatz Centrum-Berlin	Shopping center
	Casino and Supermarket (Monsdorf)	Casino and Supermarket
Japan	Ashai Brewery (Nogano)	Brewery
Luxembourg	Palais Grande Ducal and Parliament	Parliament building
	Cactus Supermarket	Supermarket
	Match Supermarket	Supermarket
	IBM Luxembourg	Office building
	ASTRON Building	Office building
	Imprimerie St. Paul	Office building
	City Concorde	Shopping center
	Banque Van Lanschot	Bank
	Dresdner Bank	Bank
	Husky	Office building
Amro Bank	Bank	
Norway	Oslo Airport	Airport
	Gardermoen Airport	Airport
	Kodak Norge Office	Office building
Spain	Carlos III University in Leganes	University
Sweden	Arlanda Airport-Stockholm	Airport
	KF Stores	Stores
United Kingdom	Middlesex University	University
	Roche Products/UK (Welwyn Garden City)	Company headquarters office building
	Heathrow Terminal 5 (four systems, cooling capacity of 6.6 MW each, ammonia charge of 1,300 kg each)	Airport

Table 10, cont'd

Country	Facility	Type of Enterprise
United States	Biosphere II Oracle (Tucson, AZ)	Demonstration center (space A/C)
	McCormick Place Convention Center (Chicago)	Convention Center
	Stanford University (Palo Alto, CA,)	University-district cooling / multiple sites
	Montgomery College (Germantown, MD)	College-district cooling of multiple sites
	USF&G (Baltimore)	Office building
	Rockford Arts & Science Museum (Rockford, IL)	Museum
	University of Miami	Marine studies center
	Blue Cross Blue Shield (Chicago)	Office tower
	Xerox Office Complex (Los Angeles)	Office tower
	Montgomery County College (Maryland)	College
	Tempest Inc, Cleveland	Office building

D.3.a Use of Ammonia in smaller cooling applications

Ammonia is typically associated with larger cooling installations. However, York Company (Johnson Controls) of Denmark produces smaller ammonia chillers, under the brand name ChillPAC, with a single-piston compressor, plate heat exchanger, liquid separator, automatic oil return and electronic control in front panel. These have been applied in radio studios, computer centers, and offices. It would be technically possible to build ammonia chillers for domestic use. However, there would need to be economies of scale to make these commercially feasible.

Table 11: Partial list of Sabroe Johnson Controls ChillPAC installations

Number	Type	End-use AC	Country
2	ChillPAC 106ER	Office Building AC	Switzerland
2	ChillPAC 116E	Food factory	Malaysia
1	ChillPAC 112E	Food factory	Korea
4	ChillPAC 112LR	Datacenter AC	Switzerland
1	ChillPAC 106S	Office building AC	Switzerland
2	ChillPAC 108S	Food factory	France
1	ChillPAC 116L	Food factory	Italy
1	ChillPAC 116E	Food factory	Turkey
1	ChillPAC 116LR	Food factory	Thailand
2	ChillPAC 112LR	Food factory	Switzerland
3	ChillPAC 116E	Food factory	UAE
2	ChillPAC 106LR	Food factory	Dubai
2	ChillPAC 116ER	Food factory	Dubai
2	ChillPAC 104L	R&D center	France
1	ChillPAC 108E	Food factory	Vietnam
1	ChillPAC 116ER	Food factory	Switzerland
1	ChillPAC 108LR	Food factory	Thailand

D.4 Solar Air-Conditioning with natural refrigerants

The use of thermal energy in industrial processes covers a broad spectrum: from cooling for refrigeration and air-conditioning to reaching up to several hundred degrees in various production processes. COOLING is the second most critical production factor in industrial processes; such as for storing perishable goods, cooling in production processes and cooling the manufacturing equipment itself. In addition, cooling is becoming increasingly important for air-conditioning office buildings, shopping malls, hospitals and many other facilities. Solar cooling solutions convert solar thermal energy directly into cooling power by means of thermally driven chillers. Solar energy solutions enable long term energy cost reductions. Combining

solar energy with natural refrigerants offers the optimal environmental and business solution for cooling applications.¹⁵²

Solar cooling systems use sorption technology, which is a type of refrigeration cycle. (They could be either absorption [liquid-liquid] or adsorption [solid-liquid].) Sorption systems typically use either ammonia or water as the refrigerant. The refrigeration cycle is similar to a conventional vapor compression cycle, but instead of a compressor, it uses a combination of an “absorber” or “adsorber” and “generator” – these essentially work to bring the refrigerant from a low pressure gas to a high pressure gas, but using heat rather than electrically-driven mechanical compression. Since these systems require heat to drive them, solar energy can be utilized to provide that heat.

Table 12: Examples of solar air-conditioning systems with natural refrigerants

Company/Installation	Country	Notes
Vicot Solar Air Conditioning	China	<p>The Vicot Solar Ammonia-Water Air Conditioning was a joint development between the Chinese company Vicot and Rocky Research of the United States. The system uses 8kg of ammonia in one 21kW unit. The modular assembly can connect up to 8 units under one control.</p> <p>The Vicot solar air conditioning system consists of three components, i.e. the solar collector, the air conditioner, and the thermal energy storage system. The solar trough collector is designed to be capable of reaching up to 300°C. A heat transfer loop transports thermal energy to the absorption air conditioner. The absorption chiller converts the high temperature heat into building cooling and heating via a hydronic chilled water system. The system facilitates 24-hour solar power driven air conditioning for cooling, heating and domestic hot water with built-in thermal energy storage. Thermal energy storage is provided via the phase change heat storage system and/or an ice storage system allowing continuous chiller and heater operation throughout the night and during cloudy days.</p> <p>The company estimates 3-5 years payback time on capital costs, depending on local irradiance conditions. The Vicot Solar Air Conditioner is applicable for the domestic, commercial and industrial sectors.¹⁵³</p>
Solar Energy Center of Gurgaon	Haryana, India	<p>In 2011, the Indian Ministry of New & Renewable Energy inaugurated the world’s highest efficiency solar thermal cooling system at the Solar Energy Center of Gurgaon in Haryana.</p> <p>The 100 kw Solar Air-Conditioning System works on triple effect absorption cooling technology using water as the system refrigerant, and has 30% higher efficiency than current available systems.</p> <p>The system has been developed in a joint collaboration between the Solar Energy Centre and M/s Thermax Limited of Pune, India, and is expected to meet the growing demand for air-conditioning in India in highly efficient and cost effective way through use of direct solar energy.¹⁵⁴</p>
Industrial Solar GmbH	Germany	<p>Industrial Solar GmbH uses solar process heat (thermal energy) for commercial and industrial heating and cooling applications with a temperature range of 130°C-400°C and cooling capacities in the single digit and lower double digit Megawatt power range. With this system, they can substitute fossil fuels in commercial and industrial processes to generate heat.</p> <p>Along with the heating aspect, by means of adsorption chillers using NH₃ and water as the refrigerant, their system can use thermal energy as means of a generator to convert heat to cold air, i.e. solar cooling.</p> <p>In 2006, the company installed their first solar cooling system with its Fresnel collector in Italy. Since then, other solar cooling systems have been installed in Germany, Spain, Tunisia and Abu Dhabi, as well as a system for a football stadium in Qatar providing the largest solar cooling system in the Middle East.¹⁵⁵</p>

¹⁵² Industrial_Solar_Company_Brochure_S.pdf

¹⁵³ www.vicot.com.cn/english/Download.pdf and Greenpeace communication with Vicot, May 2012.

¹⁵⁴ <http://pib.nic.in/newsite/erelease.aspx?relid=72973>

¹⁵⁵ Greenpeace communication with Industrial Solar GmbH, May 2012.

D.5 Desiccant, evaporative and absorption cooling

Desiccant, evaporative, and absorption cooling technologies offer alternatives to typical vapor compression systems in refrigeration and air-conditioning.

D.5.a Desiccant cooling

Desiccant cooling systems are basically open cycle systems, using water as refrigerant in direct contact with air. The thermally driven cooling cycle is a combination of evaporative cooling with air dehumidification by a desiccant (i.e., a hygroscopic material). For this purpose, liquid or solid materials can be employed. These systems use materials that attract moisture, thereby picking up humidity from incoming air and discharging it to the outdoors. The term “open” is used to indicate that the refrigerant is discarded from the system after providing the cooling effect, and the new refrigerant is supplied in its place in an open-ended loop. Therefore, only water is possible as refrigerant with direct contact to the surrounding air.¹⁵⁶

Desiccant cooling is widely used in the United States by supermarkets, chain department stores such as Wal-Mart, restaurants, hospitals, community centers, and office buildings. These systems use materials that attract moisture, thereby picking up humidity from incoming air and discharging it to the outdoors.

In 2007, Wal-Mart partnered with Munters Corporation to develop and implement a desiccant dehumidification system for its first “High-Efficiency Store” in Kansas City, Missouri. The system utilizes reclaimed heat from the refrigeration system to reactivate the desiccant system, thus allowing the normal air-conditioning equipment to run at a higher operating point. The system is expected to increase overall store energy efficiency by roughly 20%, and it is now being rolled out across the industry.¹⁵⁷

Table 13: Examples of desiccant cooling in the United States

Type of Facility	Name and Location of Facility	Equipment Supplier
Supermarket	Super Rite Foods, Inc. Baltimore, MD	
Supermarket	Cub Foods, Atlanta Georgia	
Supermarket	ShopRite, Newton, New Jersey	
Supermarket	First National Supermarket, Windsor Locks, Connecticut (33 stores)	
Supermarket	Shaw’s Supermarkets, Seabrooke, New Hampshire	
Supermarket	Harris Teeter Stores, Charlotte, North Carolina	
Supermarket	Baker’s Supermarkets, Omaha, Nebraska	
Supermarket	Big Bear Supermarkets, Westerville Ohio	
Supermarket	HEB Supermarkets, San Antonio, Texas	
Mega Store	Wal-Mart Stores Benton, AK (Season’s 4)	Munters
Mega Store	Wal-Mart Stores (various locations nationwide)	Munters
Department Store	JC Penny Department Store, White Plains, NY	Engelhard/ICC
Restaurant	Burger King, Tampa, FL	Advanced Thermal Technologies
Restaurant	Denny’s Restaurant, Clearwater, FL	Advanced Thermal Technologies
Housing	Ft. McNair Commissary, Wash. DC	Engelhard/ICC
Housing	Ft. Campbell Commissary, Ft. Campbell, KY	Engelhard/ICC
Medical Center	Willis-Knighton Medical Center, Shreveport, LA	Munters
Hospital	Northeast Baptist Hospital, San Antonio, TX	Munters
Care Facility	Jewish Home for the Elderly, Fairfield, CT	Robur
Hospital	University Hospital, Augusta, GA	SEMCO
College	The Medical College of Georgia, Augusta, GA	SEMCO
Theme Park	Walt Disney World Swan, Orlando, FL	Munters
Hotel	Park Hyatt Hotel, Wash. DC	Engelhard/ICC
Clothing Manufacturer	Liz Claiborne Inc. Montgomery, AL	Engelhard/ICC
Pharmaceutical	Powers Pharmaceutical Co. Brockton, MA	Munters
Housing	Nowlin Residence, Minneapolis, MN	Comfort Solution

¹⁵⁶ www.solair-project.eu

¹⁵⁷ <http://walmartstores.com/FactsNews/NewsRoom/6213.aspx> Wal-mart Press Release, “Wal-Mart to Open First High-Efficiency Store; Supercenter Expected to Use 20 Percent Less Energy” January 18, 2007.

D.5.b Evaporative cooling

Evaporative water coolers use heat in ambient air to evaporate water, which in turn cools the surrounding air. An evaporative cooler produces effective cooling by combining a natural process—water evaporation—with a simple, reliable air-moving system. Fresh outside air is pulled through moist pads, where it is cooled by evaporation and circulated through a house or building by a large blower. As this happens, the temperature of the outside air can be lowered as much as 30°F.¹⁵⁸ Sweating is a form of evaporative cooling of the body.

Evaporative cooling is especially efficient in dry climates, where the installation and operating costs can be significantly lower than a traditional refrigerant system. Direct, or single-stage, evaporative coolers are used on tens of thousands of homes in the western United States, as well as thousands of commercial establishments—shops, restaurants, dry cleaners, offices, warehouses, factories. They are also sold as small, portable units to cool individual rooms.

In the United States, more than 70 companies manufacture evaporative air-conditioners for residential, automotive, commercial, and industrial markets. The US Department of Energy reports that 122,000 commercial buildings in the United States use this type of cooling application.¹⁵⁹

Indirect-direct, or two-stage, evaporative air-conditioning systems are also used in numerous applications such as schools, office buildings, commercial buildings, and homes. These systems precool air in the first stage by running it through a heat exchanger; thus, the final cooled air has less humidity than in a direct or single-stage system.

Table 14: Examples of evaporative cooling installations in the United States

Facility	
America West Airlines Technical Support Facility (Phoenix AZ)	Intersil/GE Office Building (Cupertino CA)
Golden Hill Office Complex (Denver, CO)	Camelback Hospital (Scottsdale, AZ)
Colorado Springs School District, Colorado Springs, CO (multiple schools)	Cherry Creek School Districts, Aurora, CO (multiple schools)
Vacaville State Prison, Vacaville, CA	Anaconda Copper Laboratory (Tucson, AZ)
US Postal Service Bulk Mail Facility (Denver, CO)	

D.5.c Absorption cooling

Absorption systems use a heat source, such as natural gas, propane, or waste heat from a variety of processes, instead of electricity. They are used in a wide variety of commercial settings, including banks, airports, office buildings, apartment buildings, hospitals, convention centers, and large residences. They typically use water as the refrigerant and lithium bromide as the absorber. Most of the installations noted use natural gas-fired chillers, though an increasing number use solar energy as the heat source. European countries, such as Spain, Germany, and Greece, have been leaders in implementing large-scale solar absorption coolers. The largest system is owned by Gr.Sarantis S.A., a cosmetics company that uses the system to cool its manufacturing facility in Viotia, Greece.¹⁶⁰

The examples below are coded by the type of absorption system installed. Where only the manufacturer's name is indicated, the building uses a single-effect absorption chiller; and where "2x" is indicated, a double-effect absorption chiller is used. In either case, the refrigerant is water and the absorber is lithium bromide. Most of the installations noted use natural gas-fired chillers; some use high-pressure steam.

Table 15: Examples of absorption air-conditioning installations in the United States

Type of Facility	Name and Location of Facility	Equipment Supplier
Commercial/Retail/Office	Reliance Federal Savings, Garden City, NY	Carrier-2x
Bank	Canadian Imperial bank of Commerce, Toronto	Carrier-2x n
Commercial/Retail/Office	Toyota Motor Sales USA, Torrance, CA	McQuay-2x
Commercial/Retail/Office	Oklahoma Natural Gas Co. Oklahoma City, OK	McQuay-2x
Commercial/Retail/Office	Ecology and Environment Offices, Buffalo, NY	Trane
Commercial/Retail/Office	Owensboro National Bank, Owensboro, KY	Robur
Commercial/Retail/Office	Yankee Gas Services Co., Stonington, CT	Robur
Commercial/Retail/Office	Union Central Life Insurance, Cincinnati, OH	Trane-2x
Commercial/Retail/Office	AT&T, St. Louis, Mo	York-2x

¹⁵⁸ www.consumerenergycenter.org

¹⁵⁹ U.S. Department of Energy, Energy Information Administration. Consumer Commercial Buildings Energy Consumption Survey (CBECS) 2003 http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html

¹⁶⁰ http://esttp.org/cms/upload/pdf/070202_4_EUSEW_Henning.pdf. Hans-Martin Henning, Presentation for Solar Energy Week.

Table 15, cont'd

Type of Facility	Name and Location of Facility	Equipment Supplier
Commercial/Retail/Office	Merck & Co. Pharmaceuticals Headquarters, Readington, NJ	York-2x
Commercial/Retail/Office	National Audobon Society, New York, NY	York-2x
Commercial/Retail/Office	US Air, LaGuardia International Airport Terminal, New York, NY	York -2x
Commercial/Retail/Office	Pratt & Whitney, East Hartford, CT	Carrier
Educational Institution	Illinois Mathematical and Science Academy, Aurora, IL	Carrier
Educational Institution	Brandies University, Waltham, MA	Carrier-2x
Educational Institution	Texas A&M University, College Station, Texas	Carrier-2x
Educational Institution	Doane College, Crete, NE	McQuay-2x
Educational Institution	University of Toronto, Toronto, Ont.	McQuay-2x
Educational Institution	Dixon University Center, Harrisburg, PA	McQuay
Educational Institution	Oak Hill School for the Blind, Hartford, CT	Robur
Educational Institution	Estrella Mountain Community College, Phoenix, AZ	Trane
Educational Institution	Union Community College, Elizabeth, NJ	Trane
Educational Institution	Viterbo College, LaCrosse, WI	Trane-2x
Educational Institution	Northbrook Junior H.S., Northbrook, IL	York
Educational Institution	Winston Campus School, Palatine, IL	York-2z
Educational Institution	The Learning Center, Queens, NY	York-2x
Educational Institution	Walter and Lois Curtis School, Allen, TX	York-2x
Educational Institution	Rockwall H.S., Rockwall, TX	York-2x
Government Buildings	City of Mesquite, Recreation Center, Mesquite, TX	Yazaki
Government Buildings	Federal Energy Regulatory Commission HQ (FERC) Wash. DC	Trane-2x
Government Buildings	Cook County Dept. of Corrections, Chicago, IL	Trane
Government Buildings	US Courthouse and Federal Building, Phoenix, AZ	York-2x
Government Buildings	Aurora Municipal Justice Center, Aurora, CO	York-2x
Government Buildings	State of Illinois Building, Chicago, IL	York-2x
Government Buildings	Department of Employment and Training, Boston, MA	York-2x
Government Buildings	The Ohio Statehouse, Columbus, OH	York-2x
Hospitals & Health Centers	Resurrection Medical Center, Chicago, IL	Carrier
Hospitals & Health Centers	Sherman Hospital, Elgin, IL	Carrier
Hospitals & Health Centers	Little Company of Mary Hospital, Evergreen Park, IL	Carrier
Hospitals & Health Centers	Loyola Medical Center, Maywood, IL	Carrier
Hospitals & Health Centers	Jamaica Hospital Medical Center, Queens, NY	Carrier
Hospitals & Health Centers	Claremont Manor, Claremont, CA	McQuay
Hospitals & Health Centers	Scripps Clinic, San Diego, CA	York
Hospitals & Health Centers	St. Joseph Medical Center, Wichita, KS	McQuay-2x
Hospitals & Health Centers	Our Lady of Mercy Medical Center, Bronx, NY	McQuay
Hospitals & Health Centers	Rapid City Regional Hospital, Rapid City, SD	McQuay
Hospitals & Health Centers	Alexian Brothers Medical Facility, Elk Grove, IL	Trane-2x
Hospitals & Health Centers	BroMenn Regional Medical Center, Normal, IL	Trane-2x
Hospitals & Health Centers	St. Joseph Medical Center, Joliet, I	Trane-2x
Hospitals & Health Centers	Anne Arundel Medical Center, Annapolis, MD	Trane
Hospitals & Health Centers	Dept. Of Veteran's Affairs Hospital, Bronx, NY	Trane
Hospitals & Health Centers	Montefiore Medical Center, Bronx, NY	Trane-2x
Hospitals & Health Centers	Craven Regional Medical Center, New Bern, NC	Trane-2x
Hospitals & Health Centers	St. Luke's Hospital, Maumee, OH	Trane-2x
Hospitals & Health Centers	The Toledo Hospital, Toledo, OH	Trane

Table 15, cont'd

Type of Facility	Name and Location of Facility	Equipment Supplier
Hospitals & Health Centers	Baptist Medical Center, Little Rock, AK	York-2x
Hospitals & Health Centers	Copely Hospital, Aurora, IL	York-2x
Hospitals & Health Centers	St. Francis Hospital, Evanston, IL	York-2x
Hotel	Guest Quarters Suites, Chicago, IL	York -2x
Office Building	Loctite Corp. Rocky Hill, CT	Trane Co-generation
Office Building	Nestle Quality Assurance Laboratory, Dublin, OH	York-2x
Office Building	Nestle, New Lehigh Valley, PA	York-2x
Residential	Apartment Building, Chicago, IL	York-2x
Theatre	IMAX Theater, Dallas, TX	Yazaki
Airport	Norfolk International Airport, Norfolk, VA	McQuay-2x
Zoo	Jungle World, Bronx, NY	York
Convention Center	Pennsylvania Convention Center, Philadelphia, PA	York

It is important to check the primary energy ratio (PER) to determine whether or not an adsorption or absorption system is energy efficient. In regions where there is a low emission factor (kg CO₂/kW h of electricity), then the use of direct-fired sorption systems could be much less efficient than compression systems.

D.6 Co-generation cooling

Air-conditioning technologies based on the use of waste heat from on-site electricity generation have the potential to greatly reduce energy consumption. This eliminates HFC use in many large-scale applications immediately.

Table 16: Examples of cogeneration installations

Company	Details
Banque Generale du Luxembourg	The Banque Generale du Luxembourg has installed a gas fired cogeneration system that produces 90% of the bank's energy needs and 100% cooling and heating. The cooling is provided with three absorption chillers using lithium bromide as the absorbent. The bank estimates that it saves 1 million dollars in energy costs and reduces CO ₂ emissions by 6,500 tons a year. The system is American designed and installed by Trane.
Ashai Brewery	Ashai Brewery announced in 1999 that the company was installing a cogeneration energy system at the Nagoya plant, using ammonia absorption for air-conditioning and hydrocarbons for the beer vending machines. The company expects to save 400 million yen a year from the resultant energy savings.

D.7 District cooling

A district cooling system (DCS) distributes thermal energy in the form of chilled water or other media from a central source to multiple buildings through a network of underground pipes for use in space and process cooling. The cooling or heat rejection is usually provided from a central cooling plant, thus eliminating the need for separate systems in individual buildings.”¹⁶¹

DCSs today rely on a variety of cooling agents, including HFCs, ammonia, water, or the use of absorption chillers. However, the use of HFCs for DCSs is unnecessary because natural refrigerants are available and can be safely applied in large chillers. And DCSs using absorption chillers can use mixture of lithium bromide and water, “which is a more environmentally benign alternative than the cooling agents used in building-specific compressor plants, is used as a cooling agent in absorption chillers.”¹⁶²

Regardless of the refrigerant used, DCSs are a highly efficient way of delivering cooling services with potential to reduce consumption of electricity for cooling purposes by as much as 90%.¹⁶³ A centralized cooling system provides greater quality control in maintenance and servicing, reducing the rate of refrigerant leakage.

DCSs displace peak electric power demand with district cooling and storage using ice or chilled water. This benefits the local power grid by reducing peak power demand and alleviating power congestion because of power transmission limitations in cities. So district cooling not only helps cool cities, it also helps alleviate the challenges posed by high electric consumption. The economic benefits can be experienced by both the owner and the tenant, where the capital costs of control panels, internal power distribution,

¹⁶¹ National Climate Change Committee, Singapore : www.nccc.gov.sg/building/dcs.shtm

¹⁶² www.helsinginenergia.fi/kaukojaahdytys/en/os4_1.html

¹⁶³ www.helsinginenergia.fi/kaukojaahdytys/en/os4_1.html

annual maintenance, and power consumption inside the building are reduced and the cost of chillers is eliminated.¹⁶⁴

Benefits of district cooling include:

- Better quality of cooling
- Capital cost elimination
- Decrease in sound pollution
- Maximum cost-effectiveness
- Space saving
- Environmentally friendly

Common applications involve district-cooling utilities that sell chilled water to numerous customers, as well as single owner-operator-customer systems such as universities, hospitals, airports, and industrial facilities. DCSs often facilitate the use of other beneficial technologies, such as non-electric and hybrid (electric and non-electric) chiller plants, cogeneration, and trigeneration, and thermal energy storage.¹⁶⁵

DCSs exist in many parts of the world. There are about 100 DCSs in Europe¹⁶⁶. In the United States, there are approximately 2,000 DCSs, which cool 33,000 commercial buildings, plus numerous schools, institutions, and residences.¹⁶⁷ They have also been installed in the Middle East and in Singapore.

Table 17: Examples of district cooling installations

Installation	Location	System Details
Cornell University	Ithaca, New York	Delivers 20,000 tons of DCS cooling to its campus by pumping cold water into a heat exchanger from nearby Lake Cayuga. ¹⁶⁸
City of Toronto	Ontario, Canada	Delivers 50,000 tons of DCS cooling by pumping cold waters from Lake Ontario into a heat exchanger. ¹⁶⁹
Helsinki Energy	Finland	Helsinki Energy in Finland has provided cooling from its district cooling plant at the Salmisaari power plant site since 1998. The output has been 10 MW since the first stage of the cooling plant project was completed. The cooling plant has two absorption chillers and chilled water storage for evening out peak loads. Cooling energy is transmitted via a pipe network to the districts of Ruoholahti and Kampi. In addition, the outputs of the Pitäjänmäki absorption chillers and the transportable compressor cooling units in the district of Sörnäinen total 5 MW. ¹⁷⁰
National Central Cooling Co.	United Arab Emirates	The National Central Cooling Co. (PJSC)—Tabreed, a United Arab Emirates public joint stock company established in June 1998, is now one of the world’s largest district cooling utilities. Tabreed provides district cooling services throughout the GCC countries with offices in Dubai, Abu Dhabi, Ras Al Khaimah, Doha, Manama, Khobar, and Muscat. ¹⁷¹
Palm District Cooling Co.	Dubai	Palm District Cooling Co. of Dubai is working on several DCS projects in Dubai for Nakheel (a large Dubai development company), which when completed will provide combined 500,000 refrigerated tonnage. Nakheel DCS projects include Palm Jumeirah, Jumeirah Lake Towers, Jumeirah Village, Discovery Gardens and Dubai Metals and Commodities Centre, Ibn Battuta Shopping Mall and Furnished Apartments. ¹⁷²
Baltimore Aircoil Co.	USA/Global	Baltimore Aircoil Company has completed more than 2,500 installations worldwide of high efficiency [34°F (1°C) supply water] ice storage systems for district cooling. BAC has supplied ice storage systems for a wide range of projects, including office complexes, hospitals, universities, sports arenas, as well as utility districts (some as large as 125,000 ton-hours). ¹⁷³
Cool Solutions	Illinois, USA	Cool Solutions, a company based in Lisle, Illinois, has participated in the installation of DCSs in Chicago, Illinois (21,000 tons); Cincinnati, Ohio (7,500 tons); Lansing, Michigan (12,000 tons); Oklahoma City, Oklahoma (18,500 tons); Orange County, Florida (21,000 tons); Orlando, Florida (5,700 tons); and Washington, D.C. (10,000 tons). ¹⁷⁴
Lauterecken Municipality	Lauterecken, Germany	In 2011, the German municipality of Lauterecken installed a new district heating system working with a new high temperature CO ₂ heat pump. The project qualifies as investment in sustainable infrastructure and is therefore eligible to subsidies from the German Stimulus Package II. ¹⁷⁵

¹⁶⁴ www.tabreed.com/districtCoolingDistrictCoolingBenefits.aspx

¹⁶⁵ www.coolsolutionsco.com/district_cooling.html

¹⁶⁶ www.euroheat.org/

¹⁶⁷ U.S. Department of Energy, Energy Information Administration. Consumer Commercial Buildings Energy Consumption Survey (CBCECS) 2003 http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html

¹⁶⁸ Information provided by Mr. John Andrepont of Cool Solutions www.coolsolutions.com

¹⁶⁹ Ibid.

¹⁷⁰ www.helsinginenergia.fi/kaukojaahdytys/en/os3_1.html

¹⁷¹ www.tabreed.com/aboutus.aspx

¹⁷² www.palmdistrictcooling.com

¹⁷³ www.baltimoreaircoil.com/english/products/ice/district/index.html

¹⁷⁴ www.coolsolutionsco.com/district_cooling.html

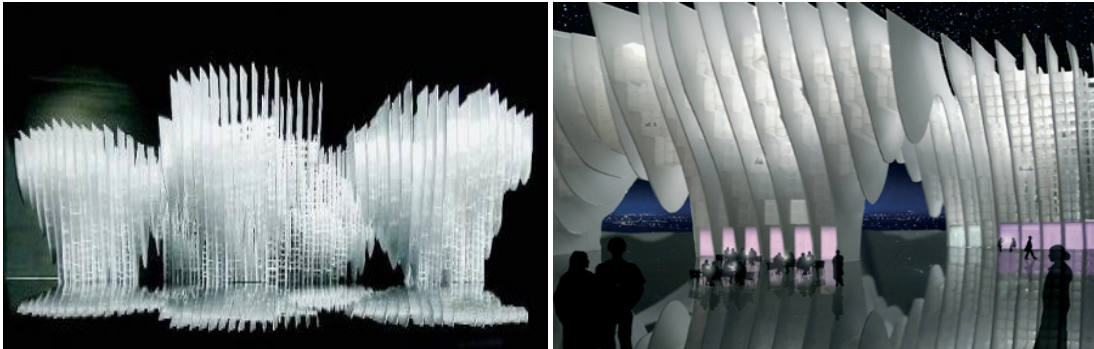
¹⁷⁵ <http://www.r744.com/articles/137220110321.php>

Business Park & Naval Base	Singapore	DCSs can be found in the Changi Business Park and Changi Naval Base in Singapore.
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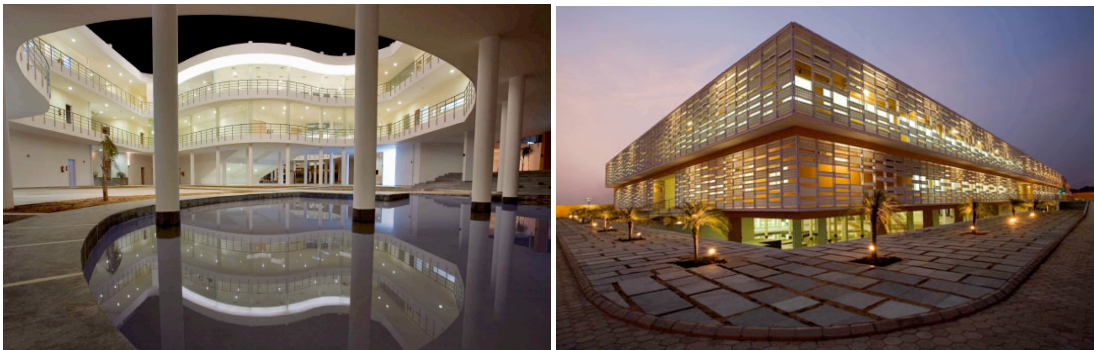
D.8 Passive cooling

Prior to modern refrigeration technology, people kept cool using natural methods: breezes flowing through windows, water evaporating from springs and fountains, as well as large amounts of stone and earth-absorbing daytime heat. These concepts were developed over millennia as integral parts of building design. Today they are called passive cooling. Passive cooling is based on the interaction between the building and its surrounding.¹⁷⁶ In some places, passive cooling can be used instead of mechanical cooling. In other places, the two can complement one another.

The architectural redesign of new buildings to make use of natural ventilation, coupled with efficient insulation, can eliminate or reduce the need for mechanical air-conditioning and thus save energy.



Swabhumi Hotel complex (model) in Kolkata, India, designed by architectural firm Morphogenesis, uses innovative building design that simulates the way trees trap winds to deliver cooling services. The firm also designed the Pearl Academy of Fashion (shown below) in Jaipur, where classrooms are cooled to around 25°C without air-conditioners, while ambient temperatures are nearly double outside.¹⁷⁷



Office building in Seattle, Washington, designed by Weber & Thomson, requires no air-conditioning. The building has green-tinted glass shades (or sunglasses) that shield windows from heat, while still allowing light into the building. Heat-reflective coating on the windows also reduce temperatures. The 40,000 square foot structure has a central courtyard, which allows cross breezes to enter all parts of the building, and allows more natural light into the building.¹⁷⁸

¹⁷⁶ <http://oikos.com/esb/51/passivecooling.html>

¹⁷⁷ Vancouver Sun: Reuters report, March 12, 2008 and www.metaefficient.com

¹⁷⁸ www.metaefficient.com

D.9 Converting from fluorocarbons to natural refrigerants

D.9.a Examples of conversions from HCFC-22 to hydrocarbons

It is widely accepted that propane and other hydrocarbons are the optimal alternative, nearly drop-in replacements for HCFC-22. Companies like Ecozone of the Netherlands, Energy Resources Group of Australia, Nat Energy Resources Private Limited of Singapore, Maple Edge Sendirian Berhad in Malaysia, APL ASIA Co in Thailand, as well as Econergy Engineering Services Ltd and Rexham Engineering Services Ltd. in Jamaica have completed numerous conversions of R-22 installations to hydrocarbons with significant energy savings. These conversions of used equipment demonstrate that hydrocarbons can be safely applied and should be an incentive to equipment manufacturers to produce new air-conditioning units with propane and other hydrocarbons.

Safety considerations: The advantage of converting to a hydrocarbon refrigerant is that it is environmentally friendly, and little or no changes need to be made to the retrofitted air-conditioning units. However, it must be ensured that the system is left in a safe condition, and that it adheres to the requirements of relevant safety standards applicable for HC refrigerants. Generally, this demands alterations to electrical components, application of marking and warning signs, and certain other changes. See *Guidelines for the Safe Use of Hydrocarbon Refrigerants*.¹⁷⁹

Table 18: Partial list of conversions from HCFC-22 to hydrocarbons

Country	Installation Site	Notes	Energy Savings (%)	Installer
Jamaica	University of West Indies: Mona Campus	Conversion of nearly 4,000 window, mini-split and central air conditioning units from HCFC-22 to R-290. Hydrocarbon units proved to require less maintenance and repair, resulting in significant cost benefits.	15 to 20% per unit	Econergy Engineering Services with Rexham Engineering
	Petroleum Corporation of Jamaica	140-ton chiller converted from HCFC-22 to R-290.		Econergy Engineering Services with Rexham Engineering
	Lascelles DeMercado	All 40 units, including min-splits and central air-conditioning units, of this retail distribution company were converted to hydrocarbons.		Econergy Engineering Services with Rexham Engineering
Singapore	Far East Square Shopping Mall	York 200TR water-cooled reciprocal chiller	16	NER180
	Defence Science and Technology Agency	Carrier 1-hp air-cooled split unit	16	ERG181
	Dapenso Building	Carrier 21TR water-cooled packaged unit	32	NER
	Watson's Stores	Daikin air-cooled split Unit	24	NER
	The Moomba Restaurant, Boat Quay	McQuay 8-hp air-cooled split unit	16	ERG
	Panasonic Refrigeration	20-hp Mitsubishi water-cooled package unit	26	NER
	Summit Building	20-hp Hitachi water-cooled package unit	20	ERG
	Kato Spring	60-hp Carrier water-cooled package unit	20	NER
	ATI	53-hp Daikin VRV2 split unit	17	NER
	Panasonic Semiconductor	50-hp Daikin water-cooled package unit	15	NER
	SignPost	5-hp Daikin air-cooled split unit	17	NER
Herbal Science	5-kW Bitzer cold room	19	NER	

¹⁷⁹ GTZ ProKlima : "Guidelines for the safe use of hydrocarbon refrigerants". 2010 : lead author Dr. Daniel Colbourne

¹⁸⁰ National Energy Resources Private Limited of Singapore

¹⁸¹ Energy Resources Group of Australia

Table 18, cont'd

Country	Installation Site	Notes	Energy Savings (%)	Installer
(Cont'd) Singapore	Orchard Hotel	3-hp Tecumseh cold room	19	NER
	Ngee Ann Polytechnic	Air-cooled split unit (demo)	19	NER
	Hitachi Chemical	23.5-hp water-cooled package unit (demo)	13	NER
	National University-Eusoff Hall	2.8-hp air-cooled split unit (demo)	17	NER
	Singapore Food Industries	25-hp Bitzer cold room (demo)	16	NER
	Singapore Food Industries	25-hp Bitzer cold room (demo)	16	NER
	Panasonic Electronics devices	18.5-hp Hitachi air-cooled package unit (demo)	13	NER
	GSK Beecham Pharmaceuticals	5-hp Daikin air-cooled split unit	15	NER
	NUS Temasek Hall	3-hp Sanyo air-cooled split unit (demo)	19	NER
	Juron Shipyard	11-hp McQuay air-cooled split unit (demo)	12	NER
	Borneo Motors	11-hp Carrier air-cooled split unit (demo)	13	NER
	Ceva Freight	150-ton R York reciprocal chiller (demo)	17	NER
	Certis Cisco	10-hp Carrier air-cooled split unit (demo)	14	NER
	Malaysia	7-Eleven Stores Kuala Lumpur	Topaire air-cooled split unit	24
Flairis Kota Tinggi		Water-cooled packaged unit	19	ERG
Nichicon Bangi		Topaire water-cooled packaged unit	20	ERG
Sumiden Electronics Shah Alam		Topaire air-cooled split unit	22	ERG
Hosiden Electronics Bangi		Air-cooled split unit	25	ERG
Alps Electric Nilai		Dunham-Bush water-cooled packaged unit	17	ERG
Panasonic AVC Network Shah Alam		Air-cooled split unit	19	ERG
Venture Technocom System Tebrau II, Johor		65–100-hp Dunham-Bush water-cooled packaged unit	23	NER
Sumitomo Electric Interconnect		1–30-hp York, National, and Topaire air-cooled, split-unit, and water-cooled package unit	21	NER
Panasonic Communication Senai Johor		National 20-hp water-cooled packaged	20	ERG
Celestica Electronics Tampoi Johor		Topaires 3x 80TR water-cooled packaged	24	ERG
Menara Ansar, Johor		Carrier 23TR water-cooled packaged	13	ERG
Bangunan PharmaCARE KL		Topaires 26TR air-cooled packaged	23	ERG
Sumitomo Electronics Tebrau II Johor		York 32TR water-cooled packaged	21	ERG
Taiko Electronics Senai, Johor		York 21TR water-cooled packaged	20	ERG
GG Circuits Industries Tampoi Johor		Carrier 35TR water-cooled packaged	14	ERG
YKJ Industries Kulai Johor		Acson 4TR air-cooled split unit	27	ERG
		Tru-Tech Electronics Ulu Tiram Johor	York 20TR air-cooled packaged	19

Table 18, cont'd

Country	Installation Site	Notes	Energy Savings (%)	Installer
(con't) Malaysia	Matsushita Electric Company Shah Alam	Carrier 35TR water-cooled packaged	15	ERG
	Menara AmFinance KL	York 21TR water-cooled packaged	16	ERG
	Li Tat Mfg Masai Johor	York 17TR air-cooled ducted type split unit	29	ERG
	OYL HQ (R&D Lab)	New 3TR split units	27	ERG
	UiTM Shah Alam Campus	Hitachi screw chiller	19.7	ERG
	Damansara Realty	Carrier 10TR packaged units	32	ERG
	Pantai Medical Centre Bangsar	York 80TR heat recovery unit	24	ERG
	Pantai Medical Centre Bangsar	York air-cooled chiller packaged	18	ERG
	Lam Wah Ee Hospital Penag	Carrier water-cooled packaged	20	ERG
	Elecan SemiConductor Penang	Air-cooled packaged	14.8	ERG
	Comfort Engineering Puchong	Carrier air-cooled packaged	18.5	ERG
	Cekap Rea Johor	National air-cooled split unit	16.7	ERG
	Nichicon (M) Sdn Bhd (Bangl, Selangor)	10–30-hp Dunham-Bush and Topair water-cooled packaged unit	21	NER
	Shinko Electronics Shah Alam, Selangor	25–36-hp Dunham-Bush water-cooled packaged unit	16	NER
	Beyonics Precision Machining	280-tonR Dunham-Bush air-cooled chiller unit	11	NER
	Koa Denko	35–50-hp Carrier water-cooled packaged unit	18	NER
	Panasonic Refrigeration Devices Cheng, Melaska	5–20-hp National and Panasonic air-cooled, split unit, and water-cooled packaged unit	15	NER
	Tsuritani Bt Berendam, Melaka	1–15-hp Topair, National, Fujitsu, and York air-cooled, split-unit, and water-cooled packaged unit	17	NER
	Jusco Melaka Shopping Centre Ayer Keroh, Melaka	75–95-hp Carrier water-cooled packaged unit	19	NER
	Sumiden Electronics Materials Shah Alam, Selangor	1–30-hp York, Carrier water-cooled packaged unit	22	NER
	Flairis Sdn Bhd Kota Tinggi, Johor	10–40-hp York, Carrier water-cooled packaged unit	19	NER
	TSB Industries, Johor	40-hp York air-cooled split unit	14	NER
	Tiong Nam Logistic Solutions, Johor	2-hp Acson air-cooled split unit	13	NER
	Hitachi Cable, Johor	25-hp Dunham-Bush water-cooled packaged unit	20	NER
	Panasonic AVC Networks, Johor	1–60-hp Carrier Dunham-Bush air-cooled, split-unit, and water-cooled packaged unit	21	NER
	Digi Telecommunications, Selangor	12.5-hp Trane air-cooled split unit	21	NER
	IDS Manufacturing, Selangor	30-hp Carrier air-cooled split unit	13	NER
	Panasonic Compressor, Selangor	4–72-hp York and National air-cooled, split-unit, and water-cooled packaged unit	16	NER

Table 18, cont'd

Country	Installation Site	Notes	Energy Savings (%)	Installer
Thailand	Carrier HQ Building	Carrier 150TR reciprocal chiller	14	ERG
	Two 7-11 stores	Split unit and walk-in-freezer	20	ERG
	Schneider Electric (Thailand) Co., Ltd.	Carrier chiller : 6 units Carrier split A/C: 20 units	18 15.5	APL ASIA182
	Thai Toray Synthetics Co., Ltd. (Hi-Tech)	York & Carrier: Split:30 units	14.50	APL ASIA
	Thai Toray Synthetics Co., Ltd. (Lardplakao)	Carrier: Split: 14 units	22.72	APL ASIA
	Dairy Plus Co., Ltd.	Trane: Split: 18 units	18.47	APL ASIA
	Inoue Rubber (Thailand) PLB. (1)	Trane: Split: 8 units	27.74	APL ASIA
	Inoue Rubber (Thailand) PLB. (2)	Trane: Split: 10 units	27.74	
	Nestle (Thailand) Co., Ltd.	Carrier: Split: 5 units	24.26	APL ASIA
	Team Precision PLB.	Carrier: Split: 3 units	13.75	APL ASIA
	Molnlycke Health Care PLB.	Carrier: Split: 38 units:	14.04	APL ASIA
	Nakhornlaung College	Fujibishi/Focus:Split: 5 units	19.69	APL ASIA
	AJ.Plus Co., Ltd.	Carrier:Chiller: 3units	18.00	APL ASIA
	NEC TOKIN Electronic (Thailand) Co., Ltd.	Carrier: Split: 11 units	16.00	APL ASIA
	S&P Syndicate Co., Ltd.	Carrier: Split: 2 units	13.24	APL ASIA
	Fujikura (Thailand) Co., Ltd.	Mitsubishi:Split: 2 units	25.90	APL ASIA
	Chachengsao City Hall	Senator: Split: 120 units	17.79	APL ASIA
	Seiko Instruments (Thailand) Co., Ltd.	Carrier:Split:20 units	15.98	APL ASIA
	Khonkean University	York: Split: 2 units	22.06	APL ASIA
	Swan Industrial Co., Ltd.	Trane: Split: 20 units Uni Aire: Chiller: 1 unit	16.25 14.79	APL ASIA
	Shinsei Co., Ltd.	Carrier: Split: 25 units Uni Aire: Chiller: 1 unit	14.80 13.00	APL ASIA
	Cannon Engineering Co., Ltd.	Daikin: Spolit: 29 units	17.74	APL ASIA
	Dusit Princess Koh Chang	Amena: Split: 5 units	16.60	APL ASIA
	Federal Electric	Uni Aire: Split: 5 units	11.20	APL ASIA
	PCTT (Fujikura Group)	Mitsubishi: Split: 3 units	21.41	APL ASIA
	APEX Circuit (Thailand) Co., Ltd.	Trane: Split: 3 units	13.23	APL ASIA
	ENKEI THAI Co., Ltd.	Trane: Split: 50 units	13.11	APL ASIA
	MCOT	York: Split: 20 units	15.12	APL ASIA
	Fuji Shinsei (Thailand) Co., Ltd.	Air Temp: Split: 9 units	18.28	APL ASIA
	NEC TOKIN Electronic (Thailand) Co., Ltd.	Daikin: Split: 15 units	14.73	APL ASIA
	Ansell Co., Ltd.	Carrier: Split: 2 units	18.41	APL ASIA
	Korat Sport Wear Co., Ltd.	Mitsubishi: Split: 7 units	13.93	APL ASIA
	Energy Design Concept Co., Ltd.	Carrier: Split: 15 units	18.18	APL ASIA
Union Frozen Products Co., Ltd.	Central Air: Split: 5 units	14.87	APL ASIA	
PB Tower	Carrier/Daikin: Split: 60 units	20.4	APL ASIA	
Kohler (Thailand) Public Co., Ltd.	Split: 4 units	13.72	APL ASIA	
Camillian Hospital	Trane: Split: 120 units	15,50	APL ASIA	

¹⁸² APL Asia Co., Ltd. Of Thailand

Table 18, cont'd

Country	Installation Site	Notes	Energy Savings (%)	Installer
Philippines	Gaisano Country Mall	50-tr Hitachi screw-type compressor	16	ERG
	Park Square One (Ayala Mall)	7.5-tr Frascold semihermetic reciprocating compressor	12	ERG
	Delsa Chemicals Office	5-tr Maneurop hermetic reciprocating compressor	14	ERG
	McDonald's Restaurant	7.5-tr Maneurop scroll-type compressor	12	ERG
	Legenda Hotel	2-tr Matsushita rotary-type compressor	19	ERG
	Federal Express (FedEx)	7-tr Copeland hermetic reciprocating compressor	21	ERG
	Iglesia ni Cristo Church	3-tr Copeland scroll-type compressor	15	ERG
	INARP Research Inc.	2-tr Matsushita rotary compressor	12	ERG
	Building Care Corporation	5-tr Copeland hermetic reciprocating compressor	20	ERG
	Mandarin Restaurant	40-tr Century screw-type compressor	17	ERG
	Robinsons Land Corporation (Galleria Mall)	Chiller: 6 units	16.3	APL ASIA
	Robinsons Land Corporation (Angeles Mall)	Chiller: 8 units	18.9	APL ASIA
	Robinsons Land Corporation (Bacolod Mall)	Chiller: 4 units	14.80	APL ASIA
	Robinsons Land Corporation (Tarlac Mall)	Chiller: 2 units	15.60	APL ASIA
	Kraft Foods Philippines Inc.	Chiller: 28 units	18.20	APL ASIA
	Sunpower MODCO	Split: 12 units	21.40	APL ASIA
	Sunpower FAB-I	Split: 6 units	19.50	APL ASIA
	Sofitel Luxury Hotel (on trial)	Split: 1 unit	22.22	APL ASIA
	EMS Component Assembly (on trial)	Split: 1 unit	14.55	APL ASIA
	Kabayan Hotel (on trial)	Split: 1 unit	19.05	APL ASIA
Indonesia (Jakarta)	Alfamart 649 stores	Air-cooled split units	25	ERG
	ITC Mangga Dua	208-tr Carrier reciprocal chillers	34.7	ERG
	JW Marriott Hotel	132-tr York reciprocal chillers	25	ERG
	Supermal Karawaci	60-tr Hitachi screw AHU	30	ERG
	Mulia Hotel	Copematic chiller	13.3	ERG
	Sol Elite Marabella Hotel	1.5-tr Sanyo split unit	24.4	ERG
	Maspion Plaza	150-tr York reciprocal chiller	15	ERG
	Kondominium Simpruk Teras	10-tr Fair packaged unit	22	ERG
	Mal Kelapa Gading	200-tr Carrier reciprocal chillers	28	ERG
	Darmawangsa Square	2-tr General split unit	24	ERG
	Siloam Gleneagles Hospital	1-tr Mitsubishi split unit	45	ERG
	Yayasan Pendidikan Permai	1-tr Gree split unit	22	ERG
Indonesia (Bali)	Maya Ubud Resort and Spa	N/A	41	ERG
	Sahid Jaya Hotel	N/A	51	ERG
	Ritz Carlton Hotel	N/A	28	ERG
	Kartika Plaza Beach Hotel	N/A	55	ERG
Indonesia (Lombok)	Sahid Jaya Hotel	N/A	72	ERG
	Oberoi Hotel	N/A	18	ERG
	Novotel Hotel	N/A	39	ERG
	Lombok Raya Hotel	N/A	27	ERG
	Sheraton Senggigi Hotel	N/A	53	ERG
	Senggigi Beach Hotel	N/A	36	ERG
	Jayakarta Hotel	N/A	25	ERG
	Intan Lombok Hotel	N/A	21	ERG
Holiday Inn Hotel	N/A	20	ERG	

D.9.b German Government Development Agency (GIZ) projects with natural refrigerants

The German Government Development Agency (GIZ) has been a world leader in the development and promotion of natural refrigerant based cooling solutions.

Table 19: Examples of GIZ ProKlima conversion technology development projects

Country	Technology Conversion and Development	Notes
South Africa	From HCFC-22 to ammonia	The German Government Development Agency (GIZ ProKlima) together with the South African Government are converting two stores, one in Cape Town and one in Johannesburg, from HCFC-22 to cascade systems with ammonia as the primary refrigerant and glycol-water solution circulating inside the stores.
Mauritius	CFC-12 and CFC-11 to ammonia	The German Government Development Agency (GIZ ProKlima), together with the Ministry of Environment of Mauritius, is converting the air-conditioning of two government buildings. Existing CFC-12 and CFC-11 chillers are to be replaced with ammonia chillers. The project is designed to demonstrate the feasibility and enhanced energy efficiency of ammonia chillers in tropical climates. The project will provide technical and safety training to engineers and service technicians. ¹⁸³
Swaziland	HFC-134a and HFC-404a to hydrocarbons	Palfridge (The Fridge Factory), with the support of GIZ ProKlima, the Multilateral Fund of the Montreal Protocol and UNDP is the first factory in Africa to have converted its entire production line to hydrocarbons. The company also developed its own prototype of SolarChill. ¹⁸⁴
China	Hydrocarbon air conditioning	In cooperation with GIZ, Gree Electric Appliances, the largest manufacturer of residential air-conditioners worldwide developed a line of high efficiency propane (R-290) domestic split air-conditioners.
India	Hydrocarbon air conditioning	In 2012, Godrej & Boyce Mfg. Co. Ltd. inaugurated a new production line for the manufacturing of split and window-type propane (R290) air-conditioners. The project was implemented in cooperation with GIZ.

¹⁸³ GTZ ProKlima : "Guidelines for the safe use of hydrocarbon refrigerants".

¹⁸⁴ GTZ ProKlima 2009 Fact sheet, www.gtz.de/proklima

E. MOBILE AIR-CONDITIONING AND TRANSPORT COOLING

E.1 Environmental impacts of HFC mobile air-conditioning

Automotive air-conditioning accounts for approximately 25% of the global production of HFC-134a. Global passenger-car production in 2010 was approximately 66 million, of which 75%, or 49.5 million, were equipped with air conditioners. In 2010, there were an estimated 600 million cars in the world with approximately 70% of them equipped with A/C, each with an average charge of 0.6 -0.8 kg of refrigerant. The total stock of refrigerant charge from the global fleet of passenger-cars was 70,100 tons in 2006, with an average leakage rate of approximately 17%.¹⁸⁵ Currently, all new mobile air-conditioning (MAC) units use HFC-134a refrigerant.

The US Environmental Protection Agency found that vehicles are the largest source of HFC emissions. They account for 56% of annual total HFC emissions in the United States. Air-conditioning accounts for over 7% of a vehicle's total greenhouse gas emissions: 4.3% from direct HFC emissions through leaks and 3.1% from CO₂ emissions related to energy use. The US Department of Energy's Energy Information Agency Web site states that "Automobile air conditioners are subject to leakage, with sufficient refrigerant leaking out (15 to 30 percent of the charge) over a 5-year period to require servicing."¹⁸⁶

A 1997 study by Atlantic Consulting reveals that the HFC-134a leakage from the air-conditioning of cars sold in 1995 in Western Europe alone will generate the CO₂-equivalent emissions of five new power plants, while the HFC-134a leakage from automobiles sold in Japan in 1995 will contribute the CO₂-equivalent of ten power plants, or approximately 16 million tons of CO₂. A study by the School of Chemical Engineering and Industrial Chemistry, University of New South Wales, indicates that hydrocarbon automobile air-conditioners are almost 35% more efficient than HFC air-conditioners. They also found that, if countries in Asia used hydrocarbons instead of HFCs in automobile air-conditioners, there would be 3.7 billion tons less cumulative CO₂-emissions by the year 2020.¹⁸⁷

E.2 Hydrocarbons in MACs

Hydrocarbons offer reliable alternatives to both CFCs and HFCs in mobile air-conditioning (MACs). The 2010 UNEP RTOC Report notes: "HCs or HC-blends, when correctly chosen, present suitable thermodynamic properties for the vapor compression cycle and permit high energy efficiency to be achieved with well designed systems."¹⁸⁸

In 2002, the Mobile Air Conditioning Society (MACS) performed a survey that found 2% of vehicles presented for repair in the United States were charged with hydrocarbon refrigerants, which equates to over 4.2 million vehicles.¹⁸⁹ Similarly, a study by the University of New South Wales estimated that 4.7 million US vehicles were charged with hydrocarbons as of 2004. The same study also documented extensive use of hydrocarbons in Australian vehicles.¹⁹⁰

Though at the present time there are no hydrocarbon-based mobile air-conditioners sold on the world market for passenger-cars, Greenpeace estimates that, globally, up to 50 million cars may have been converted, outside of regulatory framework, from CFCs and HFCs to hydrocarbons.¹⁹¹ Such routine drop-in conversions are taking place in Australia, United States, Canada, China, Panama, Philippines, Indonesia, Korea and some Caribbean countries.

E.2.a Standards and safety considerations using hydrocarbons

Since hydrocarbons are flammable, conversion from HFCs to hydrocarbons must follow standard safety procedures.

Direct Systems MAC Cooling: Hydrocarbons could be safely used in direct systems in new MAC equipment specifically designed for their usage. This would encompass keeping hydrocarbons away from spark and heat sources, automatic switch offs in case of leaks, leak detection devices, and ventilation systems.

Secondary Loop Hydrocarbon Systems: The application of a secondary loop system would further overcome any outstanding safety concerns. "Designed to accommodate a hydrocarbon, the secondary loop system would completely eliminate HFC-134a use (and emissions)." It would be expected to use

¹⁸⁵ Preparatory study for a review of Regulation (EC) (September, 2011)

No 842/2006 on certain fluorinated greenhouse gases

Annexes to the Final Report: Prepared for the European Commission in the context of Service Contract No 070307/2009/548866/SER/C4: page 212.

Authors: Dr. Winfried Schwarz, Dr. André Leisewitz, Barbara Gschrey (Öko-Recherche), Anke Herold, Sabine Gores (Öko-Institut), Irene Papst, Jürgen Usinger (HEAT International GmbH), Dr. Daniel Colbourne, Prof. Dr. Michael Kauffeld, Per Henrik Pedersen and Igor Croiset.

¹⁸⁶ <http://www.eia.doe.gov/oiaf/1605/archive/gg98rpt/halocarbons.html>

¹⁸⁷ Pham, Tuan and Aisbett, E. "Natural Replacements for Ozone-Depleting Refrigerants in Eastern and Southern Asia: School of Chemical Engineering and Industrial Chemistry, University of New South Wales," to be published by the *International Journal of Refrigeration*, in press 1998

¹⁸⁸ UNEP, 2010 Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee: 2010 Assessment Report; p.163.

¹⁸⁹ "MACs releases Refrigerant Survey Results", Mobile Air Conditioning Society Worldwide, Lansdale PA, USA, October 2002, p. 2

¹⁹⁰ Professor Ian Maclaine Cross of the University of New South Wales, "Usage and Risk of Hydrocarbon Refrigerants in Motor Cars for Australia and the United States", *International Journal of Refrigeration*, Vol. 27, No 4, 2004, pp.339-345,

¹⁹¹ Greenpeace estimate is based on above-mentioned surveys, annual growth-rates and direct stakeholder consultations.

about 10% more energy for operation than the current system but would still represent a net savings of at least 80% of equivalent greenhouse gas emissions associated with current HFC-134a systems that are operated without proper recovery and recycle during service and vehicle disposal.

One noteworthy aspect of using propane, the best hydrocarbon choice for secondary loop systems, is its availability. Propane is used universally for heating and cooking. As a result, its safe handling is widely understood and practiced by the general population in most countries, whether literate or not. This could be an advantage in the developing countries. For systems using propane, the charge for a midsize vehicle would be relatively small, on the order of 200g, based on the molecular weight of the refrigerant and the lower refrigerant charge required by the secondary loop system.¹⁹²

E.3 Carbon dioxide in MACs

The energy efficiency benefits of CO₂ systems have been known for several years. Extensive measurements carried out in 1999 at the University of Illinois showed that CO₂ MACs have at least 30% lower TEWI¹⁹³ than HFC systems.¹⁹⁴ Other studies reporting on trials comparing CO₂ prototypes against state-of-the-art R134a systems in real situations indicate that the COP of the CO₂ system was typically 25% greater than that of the R134a system.¹⁹⁵ Based on the Life Cycle Climate Performance (LCCP), a recent study by SINTEF research institute compared MAC systems' total contribution to global warming with a cradle to grave approach, highlighting several benefits of R744 MAC-systems concerning environmental performance, costs, and future potential. Namely, the R744 MAC produced up to 40% lesser emissions in hot climates (India and China) than R134a.¹⁹⁶

In addition to their environmental benefits, CO₂ systems provide a servicing cost benefit, as there is no need to recover and recycle the refrigerant at the end of life.¹⁹⁷

E.4 Transport cooling and air-conditioning

Table 20: Examples of hydrocarbon, CO₂ and evaporative cooling in mobile air-conditioning and transport cooling

Technology	Company	Notes
Hydrocarbons with Evaporative Cooling	TransAdelaide Bus Company	TransAdelaide Bus Company (now operated by Torrens Transit) in Australia installed hydrocarbon air conditioning in the drivers' compartment, while the passengers' compartment is cooled by desiccant cooling.
Hydrocarbon	OKA Motor Company / Reymer Pty LTD.	OKA, the Australian manufacturer of on/off road vehicles is the first OEM in the world to use hydrocarbon refrigerant in their mobile air-conditioning systems. The company states that by adopting hydrocarbon refrigerant, OKA produces "more efficient, more environmentally sustainable, less toxic and higher performance AC systems... all at a lower price". ¹⁹⁸
Hydrocarbon	AS Trust Holding	The US based AS Trust Holding company has developed highly efficient hydrocarbon blends R441A and R443A. These blends have been approved by the US EPA for use in refrigerators, freezers and stand alone chillers. The company has applied to the EPA for SNAP approval of these blends for MACs, as well. The company reports that R441A has been successfully tested by a cab company in Japan, with a high degree of user satisfaction and significant fuel savings.
Carbon Dioxide	Konvekta	Konvekta, the leading German manufacturer of thermo systems for commercial vehicles has begun to install CO ₂ vehicle air conditioning. Type P 7744, to be used with the natural refrigerant CO ₂ (R744), features a cooling capacity of 33 kW, and a heating capacity of 38,000 Q 100. Since 1996, it has been running successfully in test fields with a German bus operator to prove its everyday suitability. The operational experience has shown that, compared with the current refrigerant R-134a, R744 is competitive in terms of efficiency and capacity because of a better compressor performance and heat transfer, as well as a lower effect in case of pressure losses. In addition, CO ₂ units in reversed circulation can be used for heating purposes, unlike R-134a. After more than 6,000 operating hours of the CO ₂ prototypes, Konvekta is now preparing for the serial production of its R744 cooling unit. ¹⁹⁹ In 2010, Konvekta launched the CO ₂ version of its UltraLight (the world's lightest) bus air conditioner. ²⁰⁰

¹⁹² S.O. Andersen, U.S. Environmental Protection Agency, Washington DC, USA, W. Atkinson & J.A. Baker Technical Advisors to the Mobile Air Conditioning Climate Protection Partnership Existing and Alternate Vehicle Air Conditioning Systems.

¹⁹³ The sum of the direct and indirect emissions of greenhouse gases represents the "total equivalent warming impact" (TEWI) of the technologies being compared.

¹⁹⁴ J. M. Yin, J. Pettersen, R. McEnaney, and A. Beaver, "TEWI Comparison of R744 and R134a Systems for Mobile Air Conditioning", SAE paper no. 990582, 1999.

¹⁹⁵ Notes from Calor Gas reporting on studies by Walter & Krauss, 1999; Walter 1999; DKK 1998) and confirmed on Mercedes (Daimler-Benz web site (http://www.daimler-benz.com/ind_gfnav_e.html?/research/text/80331_e.htm

¹⁹⁶ http://www.r744.com/news/news_ida095.php

¹⁹⁷ Multisectorial Initiative on Potent Industrial Greenhouse Gases (MPIGGs) newsletter, 2004: www.mipiggs.org

¹⁹⁸ <http://greencooling.org/wp-content/uploads/2010/12/20101207-hychill-oka-mr-final.pdf>

¹⁹⁹ http://www.r744.com/news/news_ida319.php

²⁰⁰ <http://www.r744.com/articles/2009-08-17-world-lightest-bus-ac-by-k-onvekta-goes-into-serial-production.php>

Table 20, cont'd

Technology	Company	Notes
Carbon Dioxide	BVG	BVG is Germany's largest local transport company. In 2010, the company installed CO ₂ air-conditioning in seven buses in Berlin. The A/C systems were provided by Konvekta. Most new city buses and all long-distance buses in Germany are equipped with A/C systems with an average HFC leakage of 13-14% a year, or a total of 140,000 tonnes of CO ₂ equivalent. ²⁰¹
Carbon Dioxide cooling for shipping containers	Carrier	Under the name 'NaturaLINE', Carrier Transicold (a division of Carrier) has developed the world's first container refrigeration system using CO ₂ as the refrigerant. Working with the German shipping company Hapag-Lloyd Carrier has been testing its new system since 2010. Carrier aims for improved refrigeration performance and reduced power consumption. ²⁰² "The new NaturaLINE design has been engineered to deliver efficiencies equal to Carrier Transicold's best-in-class performer, the PrimeLINE unit...By using CO ₂ as a natural refrigerant, the NaturaLINE design improves upon the PrimeLINE unit's ability to reduce carbon dioxide emissions 28 percent compared to previous units." ²⁰³ As of August 2012, the CO ₂ system was in use by four shipping companies, worldwide.
Carbon Dioxide and dry-ice cooling for perishable goods transport	AGA	"With operations in Scandinavia and the Baltic region, AGA is currently northern Europe's leading industrial gas company and part of The Linde Group." AGA provides both "direct and indirect cooling systems. The flexibility of these systems offers the possibility to either cool trailers in total or trailers separated into different chambers or trolleys." The systems can use dry ice and carbon dioxide to refrigerate dairy, meat, frozen and other perishable food products during transportation. "Carbon dioxide cools the air in the vehicle via a heat exchanger and is then vented out through the top of the car. The system will use the warmed cooling water from the car engine to maintain the prescribed temperature in the chamber if needed. The system offers full control of temperature conditions, and is free of noise." ²⁰⁴
Evaporative Cooling	US and Australian companies	Nearly 500 buses (in Colorado, Utah, California, and Texas) and additional buses in Adelaide and Perth, Australia use evaporative or adiabatic air-conditioning systems. Facilities using evaporative cooling in transport include Regional Transportation District, Denver, CO; Denver International Airport, Denver, CO; Utah Transit Authority, Salt lake City, UT; University of California at Berkeley, Berkeley, CA; Sacramento Regional Transit, Sacramento, CA; Pacific Gas & Electric Co. CA.

E.5 HFC-1234yf (HFOs) in MACs

Because of increasing concerns regarding the high global warming potential of HFCs currently on the market, the chemical industry is now rolling out a new generation of low GWP fluorocarbon products, or unsaturated HFCs, branded as HFOs, or "hydrofluoro-olefins."

HFC-1234yf is slated to be the first HFO refrigerant to be marketed. It is to replace HFC-134a in mobile air-conditioning. Other HFO refrigerants are in the pipeline for various cooling applications. HFOs do not deplete the ozone layer and have low global warming potential, but there are significant environmental and human safety risks associated with these new substances.

Table 21: Environmental, human safety, and financial concerns with HFC-1234yf (HFOs)

Concern	Notes
Direct & Embedded GWP	The stated direct GWP of HFC-1234yf is 4. However, the embedded GWP of any given substance also needs to be considered. For example, the embedded GWP of HFC-134a is around 35 kg CO ₂ -eq. per kg of refrigerant (although it may vary slightly with individual production process) and that of CO ₂ is around 0.5, when emissions during production, as well as energy use for extraction of raw materials, heat for reactions, and so on, are considered. The embedded GWP of HFC-1234yf is not yet reported.
HCFC Ingredients	A key production ingredient of HFOs is HCFCs. This means that the production of HCFCs will need to be maintained in perpetuity to produce HFOs.

²⁰¹ <http://beta.r744.com/articles/2010-07-5-update-worlds-first-co2-bus-ac-coolsin-berlin.php>

²⁰² http://www.aga.com/international/web/lg/aga/like35agacom.nsf/docbyalias/sol_trans_cooling

²⁰³ <http://www.container.carrier.com/Carrier+Brand+Sites/Carrier+Transicold+Container/Side+Bar+Links/Home/NaturaLINE>

²⁰⁴ http://www.aga.com/international/web/lg/aga/like35agacom.nsf/docbyalias/sol_trans_cooling

Table 21, cont'd

Concern	Notes
HFO Blends	Industry is in the process of creating HFO/HFCs blends, where the bulk of the blended compound (at least 60%), will be HFC-32, with HFO 1234yf or HFO-1234ze being the minor components. These blended compounds will be marketed as HFOs, with their implied low-GWP rating. However, upon their atmospheric dissolution, these blends will revert to their basic components and will make their global warming contributions accordingly. The 20-year GWP of HFC-32 is 2330.
Trifluoroacetic Acid (TFA)	TFA is a byproduct when most HFCs breakdown. HFC-1234yf produces four to five times more TFA than the same amount of HFC-134a. The concentration of TFA in fresh water bodies around the world could have dramatic effects on plants and animals and human health.
Toxic flammability	<p>HFC-1234yf is flammable. When it burns, it releases hazardous substances such as hydrogen fluoride (HF). HF is very toxic and potentially lethal to humans in unventilated spaces. While the flammability of a substance is not an impediment for its use as a refrigerant, the toxic byproduct of a substance when it burns is of great concern to human safety.</p> <p>On September 25, 2012 Mercedes-Benz/Daimler announced that the company will not be using HFC-1234yf in its products due to flammability, toxicity and environmental concerns.²⁰⁵</p>
Reduced efficiency	HFC-1234yf has been tested to be at least 10% less efficient than HFC-134a, the substance it is meant to replace. And HFC-134a is typically 7 to 10% less efficient than hydrocarbons.
Higher costs	<p>HFC-1234yf is expected to be more than ten to twenty times more expensive than HFC-134a. High costs will provide incentives for service technicians to revert back to HFC-134a.</p> <p>The producers of HFC-1234yf type products are lobbying for GWP weighted phase down of HFCs globally. Such phase down, instead of a total phase out, is smart marketing on the part of these companies that will benefit by retaining their global monopoly. Of course, the consumers in both industrialized and developing will pay through much higher costs.</p>

The vigorous promotion of this new generation of F-gases is delaying the large-scale uptake of natural refrigerants, even though they are environmentally safe, technologically proven, and relatively inexpensive and provide the long-term solution to meeting our cooling needs.

From a precautionary perspective, given the sordid track record of fluorocarbon refrigerants, the manufacturers of HFOs should accept legal responsibility today for any and all future environmental and human safety impacts their products may cause.

²⁰⁵ <http://www.emercedesbenz.com/autos/mercedes-benz/corporate-news/mercedes-benz-independent-study-finds-new-refrigerant-to-be-dangerous/>

F. MANUFACTURERS OF COMPRESSORS USING NATURAL REFRIGERANTS

The list of manufacturers providing compressors using natural refrigerants expands year to year, as the market-demand for cooling technologies using HFC-free alternatives grows exponentially.

Table 22: Examples of compressor manufacturers using natural refrigerants

Company	Country	Equipment Details	
Bitzer	Germany/Global	Bitzer C1-C2 Octagon (subcritical) and C3-C4 (transcritical): Bitzer has developed a semi-hermetic reciprocating compressor series for subcritical CO ₂ cascade applications with a maximum operating pressure of 42 bar. The compressor series is suitable for a wide range of applications and various system configurations and has high-energy efficiency.	
ComStar International	US/Global	In 2011, ComStar International announced that together with its Chinese joint venture company it will begin offering safety certified compressors in the U.S. and overseas markets using hydrocarbon blend refrigerant R441a Targeting residential refrigerator and air conditioning applications, the hydrocarbon compressors will be manufactured in China by Hangzhou Maidi Heating & Refrigerating Equipment Co. Ltd under the Silekan brand name. ²⁰⁶	
Danfoss	Denmark/Global	Refrigerant	Notes
		HC	Full line of energy-optimized R600a compressors for all size applications including household appliances and commercial equipment. They are available in a range of voltage ratings. Some are designed specifically for tropical conditions or for direct current solar power or difficult electrical supply connections.
		CO ₂	CO ₂ compressor, type TN - tailored for light commercial applications and heat pumps, the ultra-efficient new CO ₂ reciprocating compressor was created in response to increasing customer interest in alternative refrigerants, especially for bottle coolers, vending machines, and heat pumps. The transcritical system operations required meant Danfoss had to create not only a capable compressor but also a new system control strategy and heat exchanger concept. Advantages: Low noise level, Environmentally friendly natural refrigerant, low energy consumption, high cooling capacity, high COP, high product quality, technology innovation, low running cost
Dorin	Italy	Series of semi-hermetic piston CO ₂ compressor. Dorin's SCC series is able to operate in subcritical conditions. It is suitable for cascade/brine commercial and industrial refrigeration systems.	
Embraco	Brazil/Global	Embraco has developed a CO ₂ compressor series for light commercial applications and heat pumps. At the same time, the company is working on electronic control of the system's performance (VCC), which helps improve efficiency by better monitoring the system. ²⁰⁷ All models are based on a new platform concept. Suitable for light commercial (vending machines, bottle coolers, ice cream freezers), ice machines, heat pumps, dryers. The design is a single-stage reciprocating compressor for M/HBP (medium/high back pressure).	
Emerson	Global	Produces a series of scroll compressors under the Copeland brand, for subcritical CO ₂ systems. The company also cooperates with Rivalco, an Italian supplier of commercial refrigeration equipment. ²⁰⁸	

²⁰⁶ <http://www.hydrocarbons21.com/news/view/2644>

²⁰⁷ www.r744.com/news/news_ida312.php Milan Expo features CO₂ Technology

²⁰⁸ www.r744.com/news/news_ida312.php Milan Expo features CO₂ Technology

Table 22, cont'd

Company	Country	Equipment Details
Fracold	Italy	Semi-hermetic CO ₂ compressor A 1.5 4 SK subcritical.
GEA Bock	Germany/UK	<p>Series of CO₂ Compressors—Transcritical and Subcritical options. Bock has developed a complete semi-hermetic, electrically driven compressor-series for transcritical R744 applications like industrial and commercial refrigeration or air-conditioning.</p> <p>In 2012, GEA Bock introduced the GEA Bock HC compressors, a low-cost compressor especially for use with hydrocarbons and is based on their semi-hermetic compressor product range.²⁰⁹</p>
Ixetic	Germany	R744 Compressor LAK. Suitable for all vehicle classes.
Johnson Controls		HPO/HPC high-pressure reciprocating CO ₂ compressor.
Midea	China	<p>Midea, one of China’s leading AC producers, announced in 2011 that they have completed the testing and research of their R290 compressor and that the technology is mature enough to be used in inverter air conditioner production.</p> <p>The company has commercial production capability for R290 compressors and the GMCC R290 Compressor Line officially became a Montreal Protocol Implementation Demonstration Project funded by United Nations Multilateral Fund in 2011.²¹⁰</p>
Obrist	Austria/Global	C99 CO ₂ compressor: Variable displacement—externally controlled with a swept volume of 20–40ccm. It is designed to be a simple and reliable mechanism with a reduced number of parts.
Sanyo	Japan/Global	<p>Rotary two-stage CO₂ compressor:</p> <p>Sanyo has been producing hermetic rotary compressors for transcritical CO₂ cycles since 2001. Main applications of its two-stage compressor are heat pump water heaters and vending machines.</p> <p>CO₂ compressors for heat pumps, vending machines, show cases.</p>
Tecumseh Products Company	US/Global	<p>In 2011, Tecumseh announced that they would move globally to the use of hydrocarbon refrigerants with its newly launched “Green Technology” initiative.</p> <p>The initiative dedicates resources to develop, manufacture and market compressors and condensing units that are optimized for use with hydrocarbons. With over 10 years of experience in manufacturing hydrocarbon compressors, the company already has over 150 models. In addition, in 2011 Tecumseh launched an all-new compressor for commercial refrigeration, optimized for use with both R290 (propane) and R600a (isobutane).²¹¹</p>

²⁰⁹ <http://www.hydrocarbons21.com/news/view/3153>

²¹⁰ <http://beta.hydrocarbons21.com/news/view/3064>

²¹¹ <http://www.hydrocarbons21.com/news/view/2658>

G. HFC-FREE FOAM BLOWING AGENTS AND TECHNOLOGIES

Natural blowing agents such as pentane or CO₂ can be used in all types of foam production. Several large manufacturers have been successfully using the technology for many years to produce high-quality products.²¹² As demand for foam rises, because in large part to improved insulation for housing and buildings, it is increasingly important that foam be manufactured without high-GWP blowing agents.

For example, today, hydrocarbons are widely used in substantial part of the market in the foaming sectors of both industrialized and industrializing countries.

Table 23: Percentage of the annual use of hydrocarbons in select foaming sectors globally²¹³

Sector	Blowing Agent	Industrialized Countries	Industrializing Countries	Global Total
Foam in domestic refrigerators	HC	66%	68%	67%
Foam in other appliances	HC	38%	< 1%	28%
Polyurethane foam boards and panels	HC	82%	21%	76%

G.1 Rigid extruded polystyrene (XPS)

Extruded polystyrene is used as a rigid board stock, where its moisture resistance and strength make it suitable for below-the-ground construction insulation, for example, in foundations and basement walls. Developed countries commonly use HFCs, and developing countries are still primarily using HCFCs as blowing agents, but many alternatives are emerging and being increasingly used worldwide. Water-based blowing agents and hydrocarbons are now commonly used. "It is not necessary to use HFCs as blowing agents in rigid XPS foam for the construction sector. The entire product range can be produced with CO₂ as blowing agent or using a combination of CO₂ with 2 to 3% ethanol. Overall, the target should be a complete phase-out of HFCs in the production of rigid XPS foam."²¹⁴

Table 24: Examples of companies using natural blowing agents in XPS foams

Company	Country	Blowing Agent	Application
Hamed Moussa	Egypt	Propane	Under review.
Dow Chemical	USA	CO ₂	Under review.
BASF	Germany	CO ₂	Under review.

G.2 Flexible Foams

Compared with rigid foams, flexible foams can be deformed when exposed to pressure, a characteristic required, for example, in mattresses and other furniture. In the 1990s, new techniques were developed to produce flexible foam without CFCs, including variable pressure foaming (VPF), which creates CO₂-based foam from the reaction of isocyanate and water. No blowing agents are required in this process.

Flexible foams are often used for non-cooling products like furniture, automotive applications, safety devices, and noise insulation. Many manufacturers have already switched to this process. For example, in 1998, the Multilateral Fund helped fund the conversion of four companies in Argentina from CFC-12 to carbon dioxide-based foam for mattresses, accounting for 90% of the Argentinean market.

Table 25: Examples of companies using natural blowing agents in flexible foams

Company	Country	Blowing Agent	Application
Brdr.Foltmar	Denmark	CO ₂	Under review.
KBE	Denmark	CO ₂	Under review.
Danfoam	Denmark	CO ₂	Under review.
Urepol Oy	Finland	Hydrocarbons	Insulated steel-faced and flexible-faced panels
Baxenden Scandinavia	Denmark	Isopentane	Flexible integral foam
Ecco/Bayer	Denmark/Germany	CO ₂	Flexible integral foam for shoe soles

²¹² See ProKlima, Natural Foam Blowing Agents: Sustainable Ozone- and Climate-Friendly Alternatives to HCFCs. For more information: <http://www.gtz.de/de/dokumente/gtz2009-en-proklima-nat-blow-agents.pdf>

²¹³ Kauffeld, Michael: "Availability of low GWP alternatives to HFCs: Feasibility of an early phase-out by 2020": 2012 Report commissioned by Environmental Investigation Agency (EIA), p.11.

²¹⁴ German Federal Environmental Agency [Umwelt Bundes Amt]. "Avoiding Fluorinated Greenhouse Gases: Prospects for Phasing Out". August 2011, p. 147. <http://www.umweltdaten.de/publikationen/fpdf-l/3977.pdf>

G.3 Rigid Polyurethane (PUR)

Rigid PUR insulating materials are closed-cell, rigid plastic foams that are available in many forms. Most often, this type of foam is used in construction, as in flexible-faced laminates, sandwich panels, slabstock or boardstock, spray foams, and pipe insulation. It is also used in appliance insulation.

HFC replacements for HCFC-141b in rigid polyurethane (PUR) foam include HFC-245fa, HFC-365mfc, or HFC-134a. These are potent global warming substances. For the most part they are unnecessary as there are natural blowing agents to replace HCFC-141b in most foaming applications. In 2005, hydrocarbons represented over 55% of global blowing agent usage.²¹⁵

Today hydrocarbons have become the most widely applied technology in the world for PU foams. Whereas it is sometimes reported that the thermal performance of hydrocarbons is inferior in comparison to HFCs in foams, optimized hydrocarbon foam technology today yields equal performance to that of HFC-based foams.²¹⁶

G.4 Appliances

Appliance insulation foam is used to insulate refrigeration appliances, hot water storage tanks, and similar products. With the exception of the North American market, cyclopentane is the standard choice for the rigid PUR in domestic appliances and small commercial equipment.

Germany has been a leader in converting to cyclopentane in appliances and has fully converted to this technology in domestic refrigerators. General Electric in the United States might soon be the first to enter the North American market with cyclopentane foam in new refrigerator-freezers set for production next year.

In the commercial sector, Electrificio in Brazil switched to cyclopentane based foam for refrigerated displays for chilled and frozen foods and cold stores for large supermarkets back in 1996.

In 2011, Dow introduced the Pascal technology, which is a patented, high-efficiency hydrocarbon-based polyurethane foam system for commercial and residential appliances. The Pascal system allows users to meet the US EPA's new, stricter energy efficiency regulations; the technology allows for 10% greater energy efficiency over current PU insulating systems.²¹⁷

G.5 Flexible-faced laminates

Flexible-faced laminates are used as insulating panels in the housing sector to insulate floors, saddle roofs, or under floor heating systems. Until 2004, HCFC-141b was mainly used. Today, rigid PUR insulating panels for building construction are often foamed with pentane. In Germany, 90% of flexible laminates use pentane.

G.6 Boardstock

Boardstock is mainly used as roof and wall insulation in commercial buildings, and companies are increasingly using pentane as a blowing agent in these panels. Currently, hydrocarbon foams are mainly used in developed countries, whereas developing countries are still using HCFCs.

G.7 Sandwich panels

Sandwich panels usually have foam sandwiched between materials such as steel and aluminum, and are often used to insulate roofs and walls in industrial refrigerated warehouses and cold stores. Cyclopentane is now commonly used as a blowing agent in sandwich panels, and the process has been optimized to the point where the thermal insulation is better than that of most HFCs. By 2002, four of the six large panel foam manufacturers in Argentina switched from CFC-11 to pentane as their foam-blowing agent.

²¹⁵ IPCC (2005).

²¹⁶ UNEP Technology and Economic Assessment Panel. Task Force Decision XX/8 Report: Assessment of Alternatives to HCFCs and HFCs and Update of the TEAP 2005 Supplement Report Data; 2009.

²¹⁷ <http://www.dow.com/polyurethane/markets/pascal.htm>

Table 26: Examples of natural foaming agents in construction foams

Foaming Agent	Company (Country)	Application
CO ₂	ICI (UK) Liquid Polymers Group (UK) ResinaChemie (Germany) BASF (Germany) Nassau Doors (Denmark) Windsor Doors (Norway)	Using CO ₂ as blowing agent for PUR foams.
Hydrocarbon Pentane	Atlas Roofing (USA) Firestone (USA) RMAX (USA) Johns Manville (USA)	Major US building insulation producing companies have shifted from HCFC-141b to using pentane. They have concluded that pentane is less costly and more sustainable than HFC-245fa or HFC-365 mfc
Hydrocarbon Pentane	Recticel (Belgium)	The largest manufacturer of PUR foams in Europe uses pentane for foam manufacturing.
Hydrocarbon Pentane	Bayer (Germany)	Producer of hydrocarbon construction foam.
Hydrocarbon Pentane	Efisol	Uses pentane for a variety of polyurethane foams.
Mechanical process	Thanex (Denmark)	Uses a mechanical process for producing PUR insulating foam
Methyl Formate	Foam Supplies, Inc. (USA)	The company is a manufacturer of Ecomate, a liquid blowing agent designed for use in rigid insulating foam, spray foams, integral skin foams and various flexible foams, not only in construction applications but in appliances, commercial food ware and automotive applications as well worldwide. Methyl formate is the main ingredient Ecomate, and according to the company has an ODP of 0 and a GWP of -1. ²¹⁸ Delfield Refrigeration, an American company, for example, has switched its entire foam-cooling technology of its refrigeration products to Ecomate. ²¹⁹
Methyl Formate	Purcom Quimica (Brazil)	The company is a supplier of methyl formate (Ecomate) to the South American market since 2005. Currently they have close to 700 customers, including Folle, Danica, Gelopar and Randon. ²²⁰

G.8 Spray foams

Spray foams now increasingly use CO₂, and the performance of this, while not quite equivalent to HFCs and HCFCs it replaces, is still improving and already suitable for many applications.

G.9 Pipe insulation

Pipe insulation can now be manufactured with cyclopentane and has the same performance as HFC-365mfc, the common refrigerant used. More than half of the world production of pre-insulated district heating pipes takes place in Denmark, by four companies: ABB District Heating (I C Moller), Logstor Ror, Taco Energy, and Star pipe (Dansk Rorindustri). All four companies are now producing insulation using cyclopentane or other hydrocarbons. Two of the companies also produce CO₂-based pipes.

G.10 Alternatives to foam

Often the best alternatives to polyurethane boardstock are not foams at all. Magnesium carbonate, as produced by Darchem in the United Kingdom, can be made into an insulation product for use in power stations and oil installations. Products such as mineral fiber and fiberboard have always been in competition with polyurethane. Mineral fiber is dominant in insulation products in the United Kingdom. Meanwhile, the Swiss company Isofloc produces boardstock panels made out of cellulose. The panels are made out of recycled materials.

Vacuum insulation panels, which offer superior insulation for appliances and provide significant energy savings are increasingly being applied. These vacuum panels are filled with, for example, silica, fiberglass,

²¹⁸ Communication between Foam Supplies, Inc. and Greenpeace, June 2012.

²¹⁹ <http://www.foamsupplies.com/environmentally-friendly-energy-efficiency/>

²²⁰ "Alternative Technologies in Rigid Foam for Transportation: A Folle Conversion Case": Felipe Crestani (PPT presentation). July 2012, Bangkok, Thailand.

or ceramic spacers. A global manufacturer and supplier of this type of technology is Microtherm Thermal Insulation Solutions, based in Europe and Asia.

In addition to foams manufactured with natural blowing agents, a combination of rock wool and aerogel offers efficient HFC-free insulation. Rock wool insulation refers to a type of insulation that is made from actual rocks and minerals. It also goes by the names of stone wool insulation, mineral wool insulation, or slag wool insulation. A wide range of products can be made from rockwool, due to its excellent ability to block sound and heat. Rock wool insulation is commonly used in building construction, industrial plants, and in automotive applications.²²¹

Table 27: Manufacturers of rock wool insulation

Company	Country	Application
Aerowolle	Germany	Under review.
Fujairrah Rockwool Factory	United Arab Emirates	Under review.
Minwool Rock Fibres Limited	India	Under review.
Rockwool Manufacturing Company	Global	Under review.
The Rockwool Group	Global	Under review.
Thermafiber	US/Canada	Under review.

²²¹ German Federal Environmental Agency [Umwelt Bundes Amt]. "Avoiding Fluorinated Greenhouse Gases: Prospects for Phasing Out". August 2011, p. 154. <http://www.umweltdaten.de/publikationen/fpdf-l/3977.pdf>

H. CONCLUSION

The steady growth in extreme weather events around the world signals that human-induced climate change is happening right now. Nine of the 10 warmest years in the modern meteorological record have occurred since the year 2000.²²² 2010 was one of the two hottest years on record.²²³ At the same time, according to the International Energy Agency, CO₂ emissions in 2010 reached a record high of 30.6 Gigatonnes (Gt).²²⁴ Global greenhouse gas emissions have increased 36% since the 1992 Rio Convention, despite the treaties in place to stabilize and to cut emissions.²²⁵

We are witnessing unparalleled devastation around the world from record heat waves, floods, fires, droughts, more frequent and intense tornadoes and hurricanes. Around the world millions of acres of agricultural land have been lost due to flooding, and there have been massive declines in crop harvests due to heat and drought. Sea ice and glaciers are melting at an alarming rate. In September 2012 the size of the Arctic sea ice, which has been referred to as the air-conditioner of the planet, had shrunk by 49% compared to average ice conditions between 1979 to 2000.²²⁶ There were an estimated 38 million “climate refugees” in the world in 2010.²²⁷

There is now scientific and political agreement that we must keep 21st Century temperature rise between 1.5^o-2^oC if we are to avert full-scale climate catastrophes.²²⁸ To ensure that by 2020 temperature levels do not exceed the 1.5^o-2^oC threshold, global greenhouse gas emissions must be limited to around 44 Gt of CO₂ equivalent. However, under a business as usual scenario, emissions are projected to rise to around 56 Gt, and even if all the highest climate protection ambitions of all countries are implemented and supported the global emissions are still expected to reach 49 Gt of CO₂ equivalent by 2020.²²⁹

The question then becomes: What are the most available and effective steps to reduce the flow of greenhouse gas emissions in the short term while we tackle the overall challenge of weaning the world from the dependence on fossil fuels?

HFCs are “short term climate forcing substances”. Their global warming potential is thousands of times greater than that of carbon dioxide. Their impact on the climate is most concentrated in the near term following their release into the atmosphere.

The “CO₂ equivalent emissions of HFCs increased by approximately 8% per year from 2004 to 2008”²³⁰. By 2050 their annual emissions are projected to rise to about 3.5 to 8.8 Gt CO₂eq, or to between 18 to 45% of global CO₂ emissions²³¹.

Therefore, the rapid phase out of HFCs is one of the immediate preventative measures that can be taken today to try to avoid near term climate tipping points. Their elimination by 2020 could help buy back some needed time to further tackle the challenges of reducing CO₂ emissions from fossil fuels.

Fortunately, as the **Cool Technologies: Working Without HFCs** report documents HFC-free cooling technologies are already available in most sectors and more are rapidly coming on line. Several other recent reports from UNEP, German EPA and GIZ, EU, Danish EPA and other NGOs also document the availability of environmentally safe, low GWP alternatives to HFCs.²³²

“Cool Technologies: Working Without HFCs” documents the “possible.” It demonstrates that the necessary nexus between climate protection policies and technological development is achievable in the refrigeration and cooling sectors. It is an on-going survey in progress. Greenpeace plans to routinely update this survey, and welcomes all new information regarding HFC-free cooling technologies.

Now is the time to leave behind the fluorocarbon era and to embrace technologies that do not unnecessarily harm the climate or the environment.

²²² <http://www.nasa.gov/topics/earth/features/2011-temps.html>

²²³ UN Dispatch : (January 13, 2010): reporting on NASA Goddard Institute data of January 12, 2010

²²⁴ International Energy Agency : www.iea.org/index_info.asp?id=1959

²²⁵ Steiner, Achim, UNEP Executive Director, (11/14/2011): Climate Lecture at Berlin Technical University.

²²⁶ <http://nsidc.org/arcticseaicenews/>

²²⁷ Internal Displacement Monitoring Centre: “Displacement Due to Natural Hazard-induced Disasters : Global Estimates for 2009 and 2010”:

<http://www.internaldisplacement.org/8025708F004CFA06/%28httpPublications%29/D558B66C3B055DE0C12578A7002C0FE1?OpenDocument>

²²⁸ Steiner, Achim : Op. Cit.

²²⁹ Ibid.

²³⁰ UNEP Synthesis Report (2011). “HFCs: A Critical Link in Protecting Climate and the Ozone Layer”:

http://www.unep.org/dewa/Portals/67/pdf/HFC_report.pdf

²³¹ Op.Cit. UNEP Synthesis Report (2011)

²³² Reports documenting low-GWP alternatives to HFCs: (a) UNEP: 2010 Assessment Report of the Technology and Economic Assessment Panel; (b) UNEP: 2011 HFCs: A Critical Link in Protecting Climate and the Ozone Layer : A UNEP Synthesis Report; (c) European Commission: 2011 Preparatory study for a review of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases: Annexes to the Final Report; (d) Environmental Investigation Agency: 2012: “Availability of low GWP alternatives to HFCs: Feasibility of an early phase-out of HFCs by 2020”; (e) Danish EPA: 2012: “Low GWP Alternatives to HFCs in Refrigeration”

I. APPENDICES

I.1 Efficiency comparisons between hydrocarbons and fluorocarbons

Contrary to HFC industry claims, systems using natural refrigerants are often more energy efficient than those using HFCs. Of course, there are many factors to be considered when comparing the efficiency of cooling equipment, but many studies have revealed that systems using natural refrigerants often display greater energy efficiency.

Table 28: Efficiency comparison between hydrocarbons and fluorocarbons

Application	Reference	Notes
Domestic refrigeration	Efficiency of hydrocarbons in domestic refrigeration	In 2005–2006, “the Danish Electricity Saving Trust conducted a campaign where 1000 DKK (approximately \$200 US) were given to customers buying “‘A++’ refrigerators and freezers (the most energy efficient models in the European labeling specification).” Among the 78 different appliances approved for inclusion in the campaign, 100% were based on hydrocarbon technology. ²³³
Residential air-conditioning	Efficiency of hydrocarbons in residential air-conditioning in comparison to HCFC-22	A 2007 comprehensive enquiry into the use of hydrocarbons in residential air-conditioning has shown an energy efficiency increase of up to 5.7% over R22. ²³⁴ This is accompanied with a decrease in refrigerant charge of up to 55% because of the smaller density of hydrocarbons. ²³⁵
Residential air-conditioning	DeLonghi	The Italian manufacturer De’Longhi produces small AC systems using propane as refrigerant. The cooling capacity ranges from 500 to 3,200 W, and the refrigerant charge is 100–500 g. The systems are found to have 5–10% higher efficiency than with HFCs. ²³⁶
Residential air-conditioning	Gree	Gree has developed a high efficiency propane (R-290) domestic air-conditioner with a COP of 3.52-3.55 and energy efficiency 15% better than corresponding HCFC-22 units, and a total hydrocarbon charge of less than 300g. Gree also produces hydrocarbon portable air-conditioners and dehumidifiers. The company reports 10% efficiency gains with the portable A/C units and 20% efficiency gains with the dehumidifiers. (See Section D)
Refrigerants	Efficiency of new hydrocarbon blends	2008 studies with new hydrocarbon blends, such as R-433A ²³⁷ (30% propylene, 70% propane) and R-432A ²³⁸ (80% propylene, 20% dimethylether), have shown increases in energy efficiency of up to 7.6% and 8.7%, respectively (both these blends are commercialized by Korean manufacturer MK Chemical).
Refrigerants	Survey of studies comparing COPs of hydrocarbon and HFC refrigerants	A study analyzed various papers to draw comparisons between hydrocarbons and F-gas refrigerants. They found that in 90% of the cases reviewed hydrocarbons offered higher COPs than their F-gas counterparts, with an average improvement of 10% of the COP. ²³⁹

²³³ TemaNord, 2007 : “Potent Greenhouse Gases: Ways of Reducing Consumption and Emission of HFCs, PFCs & SF6” : report prepared for the Nordic Council of Ministers

²³⁴ Park K.J., Jung D “Thermodynamic performance of HCFC22 alternative refrigerants for residential air-conditioning applications”, *Energy and Buildings* (2007), 675-680

²³⁵ Maclaine-cross I.M, Leonardi E, “Why do hydrocarbons save energy?” *Australian AIRAH Journal* 51 (1997) 33–37.

²³⁶ *Supra* no.1, private communication with Aloisi A., De’ Longhi, 2007

²³⁷ Park K.J. et al. “Performance of R433A for replacing HCFC22 used in residential air-conditioners and heat pumps” *Applied Energy* 85 (2008) 896–900

²³⁸ Park K.J. et al. “Experimental performance of R432A to replace R22 in residential air-conditioners and heat pumps” *Applied Thermal Engineering* (2008)

²³⁹ D. Colbourne and K. O. Suen, (2000) “Assessment of Performance of Hydrocarbon Refrigerants”

Table 28, cont'd

Application	Reference	Notes																											
Refrigerant comparisons	COPs of refrigerants in refrigeration systems	“Cool Pack”, is a calculation tool developed by the Danish Technical University to analyze energy efficiency. It contains thermodynamic properties for different refrigerants and algorithms for calculation of refrigeration systems. ²⁴⁰																											
		<table border="1"> <thead> <tr> <th>Refrigerant</th> <th>COP (T0=-100C, TC=+350C)</th> <th>COP (T0=+50C, TC=+450C)</th> </tr> </thead> <tbody> <tr> <td>R134a</td> <td>2.78</td> <td>3.30</td> </tr> <tr> <td>R404A</td> <td>2.53</td> <td>2.94</td> </tr> <tr> <td>R407C</td> <td>2.71</td> <td>3.15</td> </tr> <tr> <td>R410A</td> <td>2.65</td> <td>3.05</td> </tr> <tr> <td>R717 (ammonia)</td> <td>2.82</td> <td>3.41</td> </tr> <tr> <td>R290 (propane)</td> <td>2.74</td> <td>3.25</td> </tr> <tr> <td>R600a (isobutane)</td> <td>2.80</td> <td>3.36</td> </tr> <tr> <td>R1270 (propylene)</td> <td>2.73</td> <td>3.21</td> </tr> </tbody> </table>	Refrigerant	COP (T0=-100C, TC=+350C)	COP (T0=+50C, TC=+450C)	R134a	2.78	3.30	R404A	2.53	2.94	R407C	2.71	3.15	R410A	2.65	3.05	R717 (ammonia)	2.82	3.41	R290 (propane)	2.74	3.25	R600a (isobutane)	2.80	3.36	R1270 (propylene)	2.73	3.21
		Refrigerant	COP (T0=-100C, TC=+350C)	COP (T0=+50C, TC=+450C)																									
		R134a	2.78	3.30																									
		R404A	2.53	2.94																									
		R407C	2.71	3.15																									
		R410A	2.65	3.05																									
		R717 (ammonia)	2.82	3.41																									
		R290 (propane)	2.74	3.25																									
R600a (isobutane)	2.80	3.36																											
R1270 (propylene)	2.73	3.21																											
HCFC-22 replacements	Comparison of HFCs and hydrocarbons as replacements for HCFC-22	HFCs, compared with hydrocarbons, are seen as poor substitutes for HCFC-22 in heat pumps. “For example, the critical temperature of HFC-R410A is only 72°C, far less than for the previous generation HCFC-R22, which had a critical temperature of 96°C. However, propane, R290, has a critical temperature of 97°C, making it the ideal replacement for heat pump applications that would previously have used R22.” ²⁴¹																											
HCFC-22 replacements	R-22 installations Retrofitted with propane	Conversions of R-22 installation to propane typically report 15–20% energy savings. See Section C.2 of this report.																											
Air-conditioning	Comparison of hydrocarbons and fluorocarbons in compression refrigeration systems	In a 2008 study on a vapor compression refrigeration system (the most widely used method in refrigeration and air-conditioning today), a blend of R290 and R600a (propane and isobutane) gave an increase in energy efficiency of up to 25.1% at low temperatures (circa -18°C) and up to 17.4% at higher temperatures (circa +2°C). ²⁴² This was compared with CFC-12. R134a was even less efficient than R12.																											
Ice cream freezers	Unilever	By 2009 Unilever had placed over 400,000 hydrocarbon ice-cream coolers around the world, including South Africa, China, Europe, Brazil, and the United States. These coolers contain approximately 100 g of hydrocarbons and have a 9% energy savings over their HFC counterparts. ²⁴³																											
Restaurant Equipment	McDonald’s	In 2003, McDonald’s opened, as a pilot project, the world’s first HFC-free restaurant in Vejle, Denmark. The company reported that “according to TEWI calculation, during summertime (4 months) / wintertime (8 months) the emission (kg-CO ₂) from the restaurant in Vejle were 19%/32% lower than the conventional [HFC based control] restaurant in Esbjerg. The company projected that the lifetime emissions from the Vejle restaurant cooled by natural refrigerants “will be approximately 27% lower.” ²⁴⁴																											
Commercial Food Refrigeration	Foster	This UK-based company has been producing hydrocarbon-based commercial refrigeration equipment since 1996. Reports up to 15% energy savings with natural refrigerants in standalone equipment.																											
Commercial Refrigeration	True Manufacturing (USA)	True Manufacturing currently offers self-contained refrigerators and freezers with less than a 150-gram charge of R290 to foodservice and beverage customers throughout the EU. True’s line of Natural Refrigerant units consume up to 15% less energy than standard HFC systems. ²⁴⁵																											
Supermarket	Waitrose	Waitrose Supermarket of UK has announced plans to only use hydrocarbons in all new refrigeration. Designed to EN 378, the company is using a hydrocarbon-chilled water circuit (at 10° C) with water-cooled condensing units in display cabinets. The company reports 20% energy savings.																											

²⁴⁰ Pedersen, Per Henrik, Danish Technological Institute. “Low GWP Alternatives to HFCs in Refrigeration”. 2012: p. 29

²⁴¹ Cox, N., (2006) “Sustainable Cooling: Refrigerants Beyond the Crisis”, presented to the EU Commission, Brussels, Belgium

²⁴² Mani K, Selladurai V, ‘Experimental analysis of a new refrigerant mixture as drop-in replacement for CFC12 and HFC134a’, *International Journal of Thermal Sciences* (2008)

²⁴³ <http://www.unilever.com/ourvalues/environment-society/case-studies/climate-change/hydrocarbon-ice-cream-cabinets.asp>

²⁴⁴ UNEP DTIE OzonAction : HCFC Help Centre : www.unep.fr/ozonaction/topics/hcfc_case-studies.htm : McDonald’s : world’s first free HFCs restaurant.

²⁴⁵ Greenpeace correspondence with True Manufacturing, April 2012.

I.2 Efficiency comparisons between CO₂ and fluorocarbons

Table 29: Sample comparison of efficiency of CO₂ cooling with that of fluorocarbons

Application	Reference	Notes
Supermarket	Auchen (Hungary)	Company reports energy savings of at least 35% CO ₂ /ammonia cascading systems than with comparable R404a air-cooling systems. ²⁴⁶
Supermarket	Carrefour (France)	The company reports 10-15% energy savings with CO ₂ transcritical cycle refrigeration compared to HFC-404a systems. ²⁴⁷
Supermarket	Edeka (Germany)	Edeka market in the north of Germany is reporting 25% energy savings running a 100% CO ₂ transcritical system. ²⁴⁸
Mobile Air-conditioning	TEWI and LCCP studies comparing CO ₂ and R134a	The energy efficiency benefits of CO ₂ systems have been known for several years. Extensive measurements carried out at the University of Illinois in 1999 showed that CO ₂ MACs have at least 30% lower TEWI than HFC systems for most of the regions in Europe, US and Japan. ²⁴⁹ Other studies reporting on trials comparing CO ₂ prototypes against state-of-the-art R134a system in real situations indicate that the COP of the CO ₂ system was typically 25% greater than that of the R134a system. ²⁵⁰ Based on the Life Cycle Climate Performance (LCCP), a recent study by SINTEF research institute compared MAC systems' total contribution with global warming in a cradle to grave approach, highlighting several benefits of R744 MAC concerning environmental performance, costs, and future potential. Namely, that R744 MAC produced up to 40% fewer emissions in hot climates (India and China) than R134a. ²⁵¹
Vending Machines	Coca-Cola	Coca-Cola has developed a new, high-efficiency, CO ₂ technology for vending machines. Energy savings with these units average 26%. According to Coca-Cola: "some of our suppliers achieved even better CO ₂ performance versus R134a under 'D' conditions (40 degrees C ambient) . . . and in all countries in the world yearly averages are in a range where CO ₂ in beverage cold drink equipment performs better than 134a". It has been reported that Coke's CO ₂ cooler made by Haier is 35% more efficient than the ordinary HFC ones.
Vending Machines	Sanyo Electric	In 2004, Sanyo conducted field tests in Australia, comparing a CO ₂ vending machines with an existing HFC based machine. The CO ₂ system was optimized to replicate the operational factors of the HFC system. "The results showed "17% lower energy consumption by the CO ₂ system...compared to the R134a system during the summer season." ²⁵²

²⁴⁶ www.r744.com 2010-03-01

²⁴⁷ www.r744.com/news/view/3097

²⁴⁸ <http://www.r744.com/articles/2010-05-26-new-industry-report-r744-favourite-option-for-german-retailers-aldi-sued-edeka-tegut-tengelmann.php>

²⁴⁹ Yin, J., Pettersen, J., McEnaney, R., and Beaver, A., "TEWI Comparison of R744 and R134a Systems for Mobile Air Conditioning," SAE Technical Paper 1999-01-0582, 1999, doi:10.4271/1999-01-0582. <http://papers.sae.org/1999-01-0582>

²⁵⁰ Notes from Calor Gas reporting on studies by Walter & Krauss, 1999; Walter 1999; DKK 1998) and confirmed on Mercedes http://www.daimler-benz.com/ind_gfnav_e.html?research/text/80331_e.html

²⁵¹ http://www.r744.com/news/news_ida095.php

²⁵² UNEP DTIE OzonAction : HCFC Help Centre : www.unep.fr/ozonaction/topics/hcfc_case-studies.html
"CO₂ Vending Machines " by Sanyo Electric Co. Ltd.

I.3 Hydrocarbon refrigerant producers

Table 30: Partial list of hydrocarbon refrigerant producers and distributors (* indicates producer)

Name of Company	Country	Contact Information
A-Gas	UK	www.agas.com
Air Liquide Advanced Technologies	France	www.dta.airliquide.com
Air Products	USA	www.airproducts.com
BOC (Linde)	UK	www.linde.com/en/index.html
Chatcooling	Thailand	http://www.chatcooling.com
Chevron Phillips Chemical*	UK	http://www.cpchem.com/en-us/Pages/default.aspx
ComStar*	USA	http://www.comstarinternational.com/
Coolman Group	Thailand	http://www.coolman.com
Duracool	Canada	http://www.duracool.com
Ecospan	Singapore	http://www.ecospan.co.sg
Ecozone	Netherlands	http://www.ecozone.nl
Greenstar-Artek	Indonesia	http://www.greenstar-artek.com
HARP International	UK	www.harpintl.com/
Hychill	Australia	http://www.hychill.com.au
Hycool	Indonesia	http://www.hycool.co.id ?
Intergas	UK	www.intergas.co.uk
Linde	Global	http://www.linde-gas.com/en/products_and_supply/refrigerants/hydrocarbons.html
MK Chemical	Korea	http://www.mkchemical.co.kr/eng/company.html
OZ Technologies	USA	http://oztechnologyinc.com/
Pertamina Musicool	Indonesia	http://www.musicool-hc.blogspot.com/
Petrobras	Global	http://www.petrobras.com/en/home.htm
Purechem	Korea	http://www.purechem.co.kr
Quhua Yonghe Chemical Trade*		http://www.wmtag.cn/en/company/112423.html
RedTek	United States	http://www.redtek.com
Refinery of Jinling Petrochemical*	China	http://www.njlyc.com/doee/profile.htm
Settala Gas	Italy	www.settalagas.it
Shandong Jinlaier Chemical Industry Co., Ltd.	China	http://jlrchem.en.alibaba.com/
Shanghai Hynote	China	www.hynotegas.com
Shanghai Petrochemical*	China	www.spc.com
Shell*	Global	www.shell.com/
Sinochem International	China	www.sinochemintl.com
Technochem Australia	Australia	http://www.technochem.com.au
Technochem Korea	Korea	http://eng.technochem.co.kr/
Tianjin First Daily Use CH	China	http://tjfuda.en.alibaba.com

I.4 Global estimates of air-conditioner production

The following data is extracted from a 2011 report prepared for the European Commission²⁵³.

Table 31: Estimates of global air conditioning production of window and portable air-conditioners (BAU)

		Developed Countries	Developing Countries
Global fleet of window and stationary air-conditioners	Total 220 million	105 million	115 million
Annual global production	Total 16 million	9.4 million (.6 m portable & 8.8 m window)	6.6 million (.4 m portable, 6.2 m window)
Annual growth rate		1.8%	1.8%
Refrigerant type		99% HFCs 407c & 410A	90% HCFC-22 & 10% HFCs 407c & 410a
Charge size		.75kg per unit	.75kg per unit
Leakage rate		5% p.a.	10% p.a.
Lifetime		10 years	15 years

Table 32: Estimates of global production of single split type air-conditioners (BAU)

		Developed Countries	Developing Countries
Global fleet of single split air-conditioners	Total 520 million	180 million	340 million
Annual global production	Total 65.9m; 59m non-ducted, 6.9m ducted	26.3m (39.9% of total) (19.8m non-ducted, 6.5m ducted)	39.6m (60.1% of total) (39.2m non-ducted, 0.4m ducted)
Annual growth rate		+7% to 2015 +4% to 2020 0% to 2030	+4.7% to 2015 +4.7% to 2020 +4.7% to 2030
Refrigerant type		Primarily HFCs 407c & 410a	Primarily HCFC-22 with transition to HFCs by 2030
Charge size		1.5kg per unit	1.5kg per unit
Leakage rate		5% p.a.	10% p.a.
Lifetime		10 years	15 years

Table 33: Estimates of global production of multi-split air-conditioners (BAU)

		Developed Countries	Developing Countries
Global fleet of multi-split air-conditioners	Total 25 million	15 million	10 million
Annual global production	Total 3.3 million (includes conventional multi-split, VRV, VRF)	1.95m (59% of total)	1.35m (41% of total)
Annual growth rate		+5% to 2015 +3% to 2020 0% to 2030	+9.5% to 2015 +9.5% to 2020 +9.5% to 2030
Refrigerant type		100% HFCs 407c & 410a	70% HCFC-22 & 30% HFCs 407c & 410a with transition to 100% HFCs by 2030
Refrigerant charge		13.5 kg per unit	13.5 kg per unit
Leakage rate		8% p.a.	10% p.a.

²⁵³ Dr. Winfried Schwarz, Dr. André Leisewitz, Barbara Gschrey (Öko-Recherche), Anke Herold, Sabine Gores (Öko-Institut), Irene Papst, Jürgen Usinger (HEAT International GmbH), Dr. Daniel Colbourne, Prof. Dr. Michael Kauffeld, Per Henrik Pedersen and Igor Croiset.

Table 34: Estimates of global production of ducted air-conditioners (BAU)

		Developed Countries	Developing Countries
Global fleet of ducted air-conditioners	Total 21 million	17 million	4 million
Annual global production	Total 2.07m) (0.75m rooftop ducted; 0.62m close-control; 0.70m central ducted AHU)	1.73m (84% of total)	0.34m (16% of total)
Annual growth rate		-0.1% to 2015 -0.1% to 2020 -0.1% to 2030	+3% to 2015 +3% to 2020 +3% to 2030
Refrigerant type		Primarily HFCs 407c & 410a	70% HCFC-22 & 30% HFCs 407c & 410a with transition to 100% HFCs by 2030
Refrigerant charge		10.5 kg per unit	10,5 kg per unit
Leakage rate		5% p.a.	10% p.a.

Table 35: Estimates of global production of small chillers (<350 kW)

		Developed Countries	Developing Countries
Global fleet of small chillers	Total 1.8 million	1.5 million	.3m
Annual global production	Total 0.14m	0.11m (78% of total)	0.03m (22% of total)
Annual growth rate		+1% to 2015 +1% to 2020 +1% to 2030	+6% to 2015 +6% to 2020 +6% to 2030
Refrigerant type		100% HFC R134a, R407C, R410A	70% HCFC R22, 30% HFC R134a, R407C, R410A with transition to 100% HFCs by 2030
Refrigerant charge		35 kg per unit	35 kg per unit
Leakage rate		5% p.a.	10% p.a.

Table 36: Estimates of global production of large chillers (>350 kW)

		Developed Countries	Developing Countries
Global fleet of large chillers	Total 1.6 million	1.3 million	0.3 million
Annual global production	Total 0.12 million (5% centrifugal type)	0.09 m (78% of total)	0.03m (22% of total)
Annual growth rate		+1% to 2015 +1% to 2020 +1% to 2030	+6% to 2015 +6% to 2020 +6% to 2030
Refrigerant type		100% HFC R134a, R407C, R410A with 4% alternatives by 2030	70% HCFC R22, 30% HFC R134a with transition to 97 HFCs and 2% alternatives by 2030
Refrigerant charge		200 kg per unit	200 kg per unit
Leakage rate		5% p.a.	10% p.a.

Table 37: Estimates of global production of centrifugal chillers

		Developed Countries	Developing Countries
Global fleet of centrifugal chillers	Total .35 million	0.20 million	0.15 million
Annual global production	Total 0.014 million	0.008 m (78% of total)	0.006m (22% of total)
Annual growth rate		-1% to 2015 -1% to 2020 -1% to 2030	+1% to 2015 +1% to 2020 +1% to 2030
Refrigerant type		100% HFC R134a, R245fa with 5% alternatives by 2030	70% HCFC R123, 30% HFC R134a with transition to 98% HFCs and 2% alternatives by 2030
Refrigerant charge		630 kg per unit	630 kg per unit
Leakage rate		5% p.a.	5% p.a.

I.5 Contact list for companies

Table 38: Partial contact list of manufacturers and users of cooling equipment using natural refrigerants

Company	Country	Contact Information
ABN Amro	Netherlands	http://www.abnamro.com/en/index.html
AEG	Germany	http://www.aeg.co.uk/
AEON	Japan, China, Hong Kong, and Malaysia	http://www.aeon.info/en/index.html
Aerowolle	Germany	http://www.aerowolle.de/
AGA	Europe	http://www.aga.com/international/web/lg/aga/like35agacom.nsf/docbyalias/homepage
AHT Austria	Austria	http://www.aht.at/en/home/home.asp ; franz.bernkopf@aht.at
AHT UK	United Kingdom	http://www.ahtcooling.co.uk/ ; technical@uk.aht.at
Aldi Sud	Germany	http://www.aldi-sued.de/
Alpiq Intec	Switzerland	http://www.alpiq-intec.ch/en//index.jsp ; info.ecoservices@alpiq.com
Angle Vale Drakes	Australia	http://www.drakes.com.au/home
Arcelik	Turkey	http://www.arcelik.com.tr/default.aspx?lang=en-US
AS Trust Holding	United States	Contact: A.S. Trust & Holdings, 44-129 Mikiola Drive, Kaneohe, HI 96744, Email: Richard@astrust.com, tel: 808 235 1890.
Asda	United Kingdom	http://www.asda.com/
Atlas Roofing	United States	http://www.atlasroofing.com/general2.php?section_url=141
Autosal	Argentina	http://www.autosal.com.ar/
Auchan	Hungary	http://www.auchan.hu/
AUX	China	http://www.cnaux.com/
Axima Refrigeration GDF Suez		http://www.aximaref.com/
Bar Fridges	Australia	http://www.bar-fridges-australia.com.au/
BASF	Germany	http://www.basf.com/group/corporate/en/
Bauknecht	Germany	http://www.bauknecht.com/pages/pre_home_bk.html
Baxenden Scandinavia	Denmark	http://www.baxchem.co.uk/
Bayer	Germany	http://www.bayer.com/
Ben & Jerry's	USA	http://www.benjerry.com/
Binzhou Sky Rainbow	China	http://www.skyrainbow.com.cn/ ; tianhong_chuye@163.com
Bitzer	Germany/Global	http://www.bitzer.de/eng/Home
Benson Air-Conditioning	Australia	http://www.bensonairconditioning.com.au/
Blupura	Italy	http://www.blupura.com/eng/index.html ; info@blupura.com
Booths	United Kingdom	http://www.booths.co.uk/
Bosch	Germany/Global	http://www.bosch-home.com/us/
Brastemp	Brazil	http://www.brastemp.com.br/
Brdr. Foltmar	Denmark	Contact: Brdr. Foltmar A/S, info@carpenter-dk.com, tel: 0045 86 75 37 00, Fax: 0045 86 75 37 77.
Bundgaard Kølleteknik	Denmark	http://www.coolcare.dk/velkommen.html
BVG	Germany	http://www.bvg.de/index.php/en/index.html
Carlsberg	Denmark, Sweden and Switzerland	http://carlsberg.com/flash.html
Candy Group	Italy	http://www.candy-group.com/eng/gruppocandy/index.htm
Caravell (a division Metalfrio Solutions)	Denmark	http://www.caravell.dk/

Table 38, cont'd

Company	Country	Contact Information
Carrier (NaturaLine)	Global	http://www.container.carrier.com/Carrier+Brand+Sites/Carrier+Transicold+Container/Side+Bar+Links/Home/NaturaLINE
Carrier Corp and Carrier Commercial Refrigeration	US/Global	http://www.carrier.com/Carrier+Corporate+Sites/Corporate ; http://www.carrier-refrigeration.com/
Carrefour	France/Europe	http://www.carrefour.com/
Carter Retail Equipment	United Kingdom	http://www.cre-ltd.co.uk/ ; info@cre-ltd.co.uk
Coca-Cola		http://www.coca-cola.com/en/index.html
ComStar International	US/Global	http://www.comstarproducts.com/
Condor	Brazil	http://www.condor.com.br/content/default/
Continental	US	http://www.continentalrefrigerator.com/
COOP	Switzerland	http://www.coop.ch/pb/site/uebercoop/node/11393/Lde/index.html
Countdown Auckland	New Zealand	http://www.countdown.co.nz/
Criocabin	Italy/Global	http://www.criocabin.com
CSC Group	Canada	http://www.groupecsc.com/index_en.php ;
Danfoss	Denmark/Global	http://www.danfoss.com/OtherSites/NAdirect/group+global
Danone	Denmark, Mexico and Germany	http://www.danone.com/en/company/global-presence.html
De'Longhi	Italy	http://www.delonghi.com/ca_en/agency/
Derby (a division Metalfrio Solutions)	Middle East and Europe	http://www.derby.dk/
Delhaize Group	Belgium	http://www.delhaizegroup.com/en/Home.aspx
Dorin	Italy	http://www.dorin.com/jsp/Template2/HomePage.jsp
Dow Chemical	USA	http://www.dow.com/
Drakes	Australia	http://www.drakes.com.au/about
DSI	Denmark	http://www.dsi-as.com/ ; dsi@dsi-as.com
Earthcare Products Ltd.	United Kingdom	http://www.earthcareproducts.co.uk/ ; info@earthcareproducts.co.uk
Earthcool Ltd.	United Kingdom	nicholas.cox@earthcool.co.uk
Edeka	Germany	http://www.edeka.de/EDEKA/Content/Home/index.jsp
Efisol	France	http://www.efisol.fr/
Elcold	Denmark	http://www.elcold.com/GB.aspx ; elcold@elcold.com
Electrolux	Global	http://www.electroluxappliances.com/kitchen-appliances ; robcsika47@freemail.hu
Embraco	Brazil/Global	http://www.embraco.com/Default.aspx?tabid=40
Emerson	Global	http://www.emerson.com/en-us/about/overview/global-operations/Pages/default.aspx
Enex	Italy	http://www.enex-ref.com/Default.aspx ;
Eurospar (a division of SPAR Austria Group)	Austria	http://www.eurospar.ie/
Fakta	Denmark	http://www.fakta.dk/
Firestone	United States	http://www.firestone.com/
Fisher & Paykel	New Zealand	http://www.fisherpaykel.com/product/fridge-freezer/fridge/
Foam Supplies Inc.	United States	http://www.foamsupplies.com/

Table 38, cont'd

Company	Country	Contact Information
Fogel Group	Guatemala, Ecuador and Columbia	http://www.fogel-group.com/en ; fogel@fogelandina.com , foca@fogel-group.com
Foodland IGA	Australia	http://www.foodlandsa.com.au/internet/index.html
Foster Refrigeration Ltd.	United Kingdom	http://www.fosterrefrigerator.co.uk/
Framec	Italy/Global	http://www.framectrade.it/eng/framec_trade_contatti.htm
Frascold	Italy	http://www.frascold.it/econtacts.htm
Fresh & Easy Neighborhood Market (Tesco USA)	United States	http://www.freshandeasy.com/
Frestech	China	http://www.chinaxinfei.com/en_xinfei/index.aspx ; export@xinfei.com
Frigadon	Sweden	http://www.frigadon.se/eng/?q=node/60
Frigoglass	Greece	http://www.frigoglass.com/ ; vzafolia@frigoglass.com
Frost-Trol	Spain	http://www.frost-trol.com/en ; info@frost-trol.com
Fujairah Rockwool Factory	United Arab Emirates	http://www.rockwoolfujairah.ae/
GEA Bock	Germany/UK	http://www.bock.de/en/home.html
General Electric	US/Global	http://www.geappliances.com/
George Barker & Co. (EPTA)	United Kingdom	http://www.georgebarker.co.uk/
Giant Food Stores (Ahold USA)	United States	http://www.giantfood.com/about_us/index.htm
Godrej and Boyce	India	http://www.godrejappliances.com/ ; smartcare@godrej.com
Gorenje	Germany/Global	http://www.gorenje.com/
Gram Commercial	Denmark/Europe	http://www.gram-commercial.com/ ; anhu@gram-commercial.com
Grasso GmbH	Germany	http://www.grasso.nl/en-us/Pages/default.aspx
Gree Electric Appliances	China	http://www.gree.com.cn/english/aboutgree/companyIntro.jsp?catid=1204
Green & Cool	Nordic Countries and Switzerland	http://www.greenandcool.com/home
Haglund Industri	Sweden	http://www.haglundindustri.se/ ; hakan@haglundindustri.se
Haier	China	http://www.haieramerica.com/
Hamed Moussa	Egypt	http://www.hamedmoussa.net/file/we_e.html
Hartono Istana Electronics	Indonesia	http://www.polytron.co.id/
Hill Phoenix	US/Global	http://www.hillphoenix.com/ ; debbie.jones@hillphoenix.com
Hindustan Refrigerator	India	http://www.higroupworld.com/
Hitachi	Japan	http://www.hitachi.com/
Husky Group	UK/Global	http://www.husky-global.com/ ; info@husky-global.com
Ica Sweden	Sweden	http://www.ica.se/Eng-sektion/
Indesit	Global	http://www.indesitcompany.com/inst/en/index.jsp
Industrial Solar GmbH	Germany	http://www.industrial-solar.de/cms/
Infrico	Spain/Global	http://infrico.us/empresa.php ; operations@infrico.com

Table 38, cont'd

Company	Country	Contact Information
Interlevin Group	UK/Europe	http://www.interlevin.co.uk/index.ihtml
Ixetic	Germany	http://www.ixetic.com/en/kontakt/index.pmode
Johnson Controls	Global	http://www.johnsoncontrols.com/publish/us/en.html
Johns Manville	United States	http://www.jm.com/
Kältetechnik Dresen + Bremen	Germany	http://www.dresen-kaelte.de/start.html
Kelon	China	http://www.kelon.com/
Klimasan (a division Metalfrio Solutions)	Turkey, Middle East and Europe	http://www.metalfrio.com.br/site/klimasan/en/producao/introducao/introducao.aspx
Knudsen Kolling	Denmark	http://www.knudsenkolling.dk/ ; k-k@knudsen-k.dk
Konka	China	http://www.kelon.com/investor/about/company/
Koxka (part of Ingersoll Rand companies)	Global	http://www.koxka.com/eng/index.htm
Kuvatek	Denmark	http://www.kuvatek.dk/ ; kvt@kuvatek.dk
KWN Engineering- Gesellschaft	Austria	Sommerweg 13, Seekirchen, Salzburg 5201, Austria. tel: +43 621278330
Luvata	Italy	http://www.luvata.com/zh-cn/
Lidl	Germany	http://www.lidl-info.com/cps/rde/xchg/country_selection
Liquid Polymers Group	United Kingdom	7 Wardour Court, Tisbury, Salisbury, Wiltshire, SP3 6QX, United Kingdom.
Liebherr	Global	http://www.liebherr-appliances.com/
LG Electronics Inc.	Global	http://www.lg.com/ca_en
Maja	Germany	http://www.maja.de/dp_content.php?item=535_12545; maja@maja.de
Mark & Spencer	Global	http://www.marksandspencer.com/
Makro South Africa	South Africa	http://www.makro.co.za/
M & M Refrigeration	USA	http://www.mmrefrigeration.com/ ; olec@mmrefrigeration.com
Manitowoc Food Services	United States	http://www.manitowocfsusa.com/sustainability
Mayekawa	Japan	http://www.mayekawa.co.jp/ja/
McDonalds	Global	http://www.aboutmcdonalds.com/mcd.html
Meilling	China	http://www.meiling.com/en/about.php
Metro	Germany	http://www.metrogroup.de/internet/site/metrogroup/node/9251/Len/index.html
Midea	China	http://www.midea.com.cn/zh/app/home/index.htm
Miele	Germany	http://www.miele.com/international/enint/home.htm
Migros	Switzerland	http://www.migros.ch/de
Minwool Rock Fibres Limited	India	http://www.minwool.com/contact-us.htm
Morrisons	United Kingdom	http://www.morrisons.co.uk/
Nassau Doors	Denmark	http://www.nassaudoor.com/en/About%20NASSAU.aspx
Nestle	Global	http://www.nestle.com/Pages/Nestle.aspx
Netto	United Kingdom/ Denmark	http://www.netto.dk/Pages/Forside.aspx
Nuttalls	United Kingdom	http://www.nuttalls.co.uk/fsc-home.html ; freshfood@nuttalls.co.uk
Obrist	Austria/Global	http://www.obrist.at/
Oka Motor Company/ Reymer Pty LTD.	Australian	http://www.oka.com.au/

Table 38, cont'd

Company	Country	Contact Information
Palfridge (The Fridge Factory)	Swaziland/Africa	http://www.palfridge.com/ ; info@palfridge.com
PepsiCo		http://www.pepsico.com/
Pick n Pay	South Africa	http://www.picknpay.co.za/picknpay/content/en/about-us-introduction
Prodega Cash & Carry	Switzerland	http://www.prodega.ch/DE/Home/Pages/willkommen.aspx
Purcom Quimica	Brazil	http://www.purcom.com.br/apurcom/apurcom.php?lang=en
Quelle	Germany	http://www.quelle.de/
Recom Engineering	Australia	http://www.recom-eng.com.au/
Red Bull	Global	http://www.redbull.com/cs/Satellite/en_INT/Red-Bull.com/001242745950125
RMAX	United States	http://www.rmax.com.au/about-rmax.html
ResinaChermie	Germany	http://www.resina.nl/#
Recticel	Belgium	http://www.recticel.com/
Rewe	Germany	http://www.rewe.de/
Roche	Switzerland	http://www.roche.com/index.htm
The Rockwool Group	Global	http://www.rockwool.com/about+the+group
Sabro and Johnsons Control	Global	http://www.sabro.com/site/
Sainsbury's	United Kingdom	http://www.sainsburys.co.uk/sol/index.jsp
Samsung	China	http://www.samsung.com/cn/#latest-home
Sanyo Electric (Panasonic)	Japan/Global	http://panasonic.net/sanyo/index.html
Sharp	Japan	http://sharp-world.com/
Siemens Home	Germany	http://www.siemens-home.com/
Sobeys	Canada	http://www.sobeys.com/Choose-Store.aspx?returnURL=%2fen%2fHome.aspx
Star Market	United States	http://www.shaws.com/ (owned by Shaw/Supervalu)
Star Refrigeration	United Kingdom	http://www.star-ref.co.uk/
Staycold	South Africa, Australia and the United Kingdom	http://www.staycold.co.za/ ; info@staycold.co.za
Stop & Shop (Ahold USA)	United States	http://www.stopandshop.com/
Supervalu (Albertsons)	United States	http://www.supervalu.com/sv-webapp/
Target	United States	http://www.target.com/
Tecumseh	US/Global	http://www.tecumseh.com/en/canada
Tegut-gute Lebensmittel	Germany	http://www.tegut.com/
Tengelmann Group	Germany	http://tengelmann.de/
Tesco	United Kingdom/ China/Hungary/ Thailand	http://www.tesco.com/
Thanex	Denmark	http://www.thanex.dk/
The Co-operative Food Group	United Kingdom	http://www.co-operative.coop/
Thermafiber	USA	http://www.thermafiber.com/
Thermaxindia	India	http://www.thermaxindia.com/
Toshiba	Japan	http://www.toshiba.co.jp/index.htm
Trox Aitcs Ltd.	United Kingdom	http://www.troxaitcs.com/aitcs/ ; usa@@troxaitcs.com

Table 38, cont'd

Company	Country	Contact Information
True Energy	United Kingdom	http://www.trueenergy.com/success-street-lights-uk.aspx
True Manufacturing	United States	http://www.truemfg.com/ ; SProctor@truemfg.com
UBC Group	Ukraine	http://old.beer-co.com/aboutus/?lng=eng
Unilever	Global	
United States Cold Storage	United States	http://www.uscold.com/ ; mlynch@uscold.com
Verco	United Kingdom	http://www.ver.co.uk/ ; bob@ver.co.uk
Verdemar	Brazil	
Vestfrost Solutions	Denmark	http://vestfrostolutions.com/ ; http://vestfrost.dk/
Vicot Solar Air Conditioning	China	http://www.vicot.com.cn/english/index.asp
Voltas	India	http://www.voltas.com/
Waitrose	United Kingdom	http://www.waitrose.com/
Walmart	United States	www.walmart.com
Warehouse	New Zealand	http://www.thewarehouse.co.nz/red/
Windsor Doors	Norway	http://www.windsor.no/
Wegmans	United States	http://www.wegmans.com/webapp/wcs/stores/servlet/HomepageView?storeId=10052&catalogId=10002&langId=-1
Whirlpool	Italy/Argentina	http://www.whirlpool.it/ http://www.whirlpool.com.ar/
Williams Refrigeration	United Kingdom, China and Australia	http://www.williams-refrigeration.co.uk/
Woolworths	Australia	http://www.woolworths.com.au/wps/wcm/connect/webSite/Woolworths/
York (Johnson Controls)	Denmark/Global	http://www.johnsoncontrols.com/content/us/en.html
Zanussi Electrolux	Italy	http://group.electrolux.com/en/brand-zanussi-344/