HFC-Free Technologies Are Available in the US Market for the Supermarket-Retail Refrigeration Sector:

Members of the Consumer Goods Forum and retailers worldwide have the tools they need to begin installing HFC-Free technology today and to exclusively install HFC-free equipment by 2015.

A MARKET EVALUATION PREPARED BY THE ENVIRONMENTAL INVESTIGATION AGENCY WITH THE ASSISTANCE OF IFC CONSULTING

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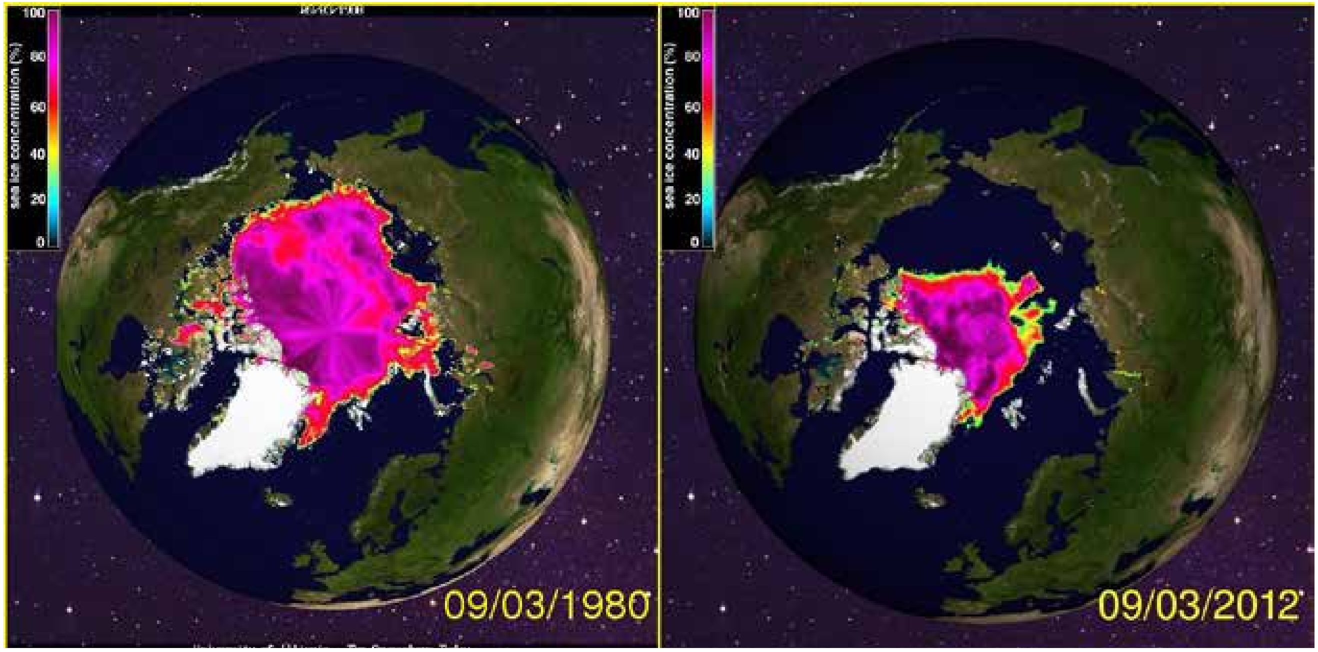
EXECUTIVE SUMMARY



Antarctic rates of glacial melt and movement continue to accelerate beyond previous high-end estimates.

The United States has seen the warmest 12-month period on record this year, with average temperatures 3.3°F above the long-term average. (NOAA 2012). Harmful greenhouse gas emissions must be reduced. Fast-acting mitigation is needed to offset increasing climate impacts, reduce the risk of passing tipping points for abrupt and non-linear climate change, and provide time needed to control emissions of carbon dioxide (CO_2) through emissions reductions and carbon-negative strategies. Reducing production and use of hydrofluorocarbons (HFCs) is the largest, fastest and most cost-effective mitigation option currently available. Fast action to reduce HFCs will virtually eliminate one of the six Kyoto Protocol greenhouse gases (GHGs) and prevent between 87 and 146 $GtCO_2e$ emissions by 2050 from a business as usual (BAU) scenario. Today, HFCs are the most commonly used refrigerants in new retail food applications in the United States, but are potent greenhouse gases (GHGs) with global warming potentials (GWPs) ranging from hundreds to thousands of times higher than CO_2. HFCs have been commercialized to replace chlorofluorocarbon (CFC) and hydrochlorofluorocarbon (HCFC) refrigerants, which have been or currently are being phased-out under the Montreal Protocol on Substances that Deplete the Ozone Layer (Montreal Protocol). Even though efforts are being made in the Unites States to minimize emissions of HFCs from the retail food sector, current and projected GHG emissions associated with HFCs are still significant.

Fast-acting mitigation is needed to offset increasing climate impacts, and the most cost effective option avaliable is to reduce HFCs.

Fortunately, a variety of climate-friendly refrigerant alternatives are currently available in retail food applications, including hydrocarbons such as propane (R-290), carbon dioxide (CO_2 and R744), and ammonia (R-717) and some “not-in-kind” technologies are being developed.

TABLE 1: SUMMARY OF REFRIGERATED EQUIPMENT IN USE BY STORE/APPLICATION TYPE

EQUIPMENT TYPE	CONVENIENCE STORES	SUPERMARKETS AND HYPERMARKETS	WAREHOUSES AND DISTRIBUTION CENTERS	TRANSPORTERS
SELF CONTAINED UNITS	X	X		
REMOTE DISPLAY CASES/WALK-INS	X	X		
PACKAGED SYSTEMS	X		X	
CONDENSING UNITS	X	X	X	
RACK SYSTEMS		X	X	
CENTRAL PLANTS			X	
REFRIGERATED TRANSPORT SYSTEMS				X

To aid efforts to reduce emissions of HFCs, the Consumer Goods Forum (CGF)—a global industry network consisting of retailers, manufacturers, service providers, and other stakeholders—agreed in 2010 to "begin phasing-out hydrofluorocarbon (HFC) refrigerants as of 2015 and replace them with non-HFC refrigerants (natural refrigerant alternatives) where these are legally allowed and available for new purchases of point-of-sale units and large refrigeration installations" (CGF 2010).

GHG emissions associated with refrigerant leaks from just one supermarket over the commercial life of the refrigeration system could be equivalent to more than 2,000 $MTCO_2eq$, or the annual GHG emissions from roughly 350 passenger vehicles.

Although all commercial refrigeration technologies are based on the same fundamental vapor compression principles, the refrigerant selected, system design, and equipment components used by each end-user differ depending on the application and varying refrigerated capacity needs. Convenience stores, supermarkets, hypermarkets, warehouses, distribution centers, and refrigerated vehicles all have different refrigeration needs and technical considerations must be included in decisions to select the correct HFC-free refrigerant for each application The common types of refrigerated equipment used in the United States include self-contained units (e.g., vending machines, reach-in cases), remote display cases and walk-ins, condensing units, rack systems, packaged systems, central plants, and transport systems (e.g., refrigerated trucks). Table 1 above summarizes the major types of refrigerated equipment used and the types of applications where they are used.

Virtually all of supermarket and retail refrigeration equipment can be designed to use natural refrigerants in place of HFCs, focusing on those technologies that have been commercially proven and therefore can be used by CGF members to meet their 2015 pledge. For example, self-contained refrigeration units containing hydrocarbons are widely used around the world, and CO_2 in vending machines are also gaining global market share. CO_2 is also being used in transcritical rack systems or in indirect or cascade designs with ammonia as the primary refrigerant. Additionally, central plants commonly use ammonia as their sole refrigerant or in a cascade design with CO_2. In refrigerated transport applications, certain condensing units and package system designs are using CO_2 and hydrocarbons are starting to become available in parts of

"Begin phasing-out hydrofluorocarbon (HFC) refrigerants as of 2015 and replace them with non-HFC refrigerants (natural refrigerant alternatives) where these are legally allowed and available for new purchases of point-of-sale units and large refrigeration installations"

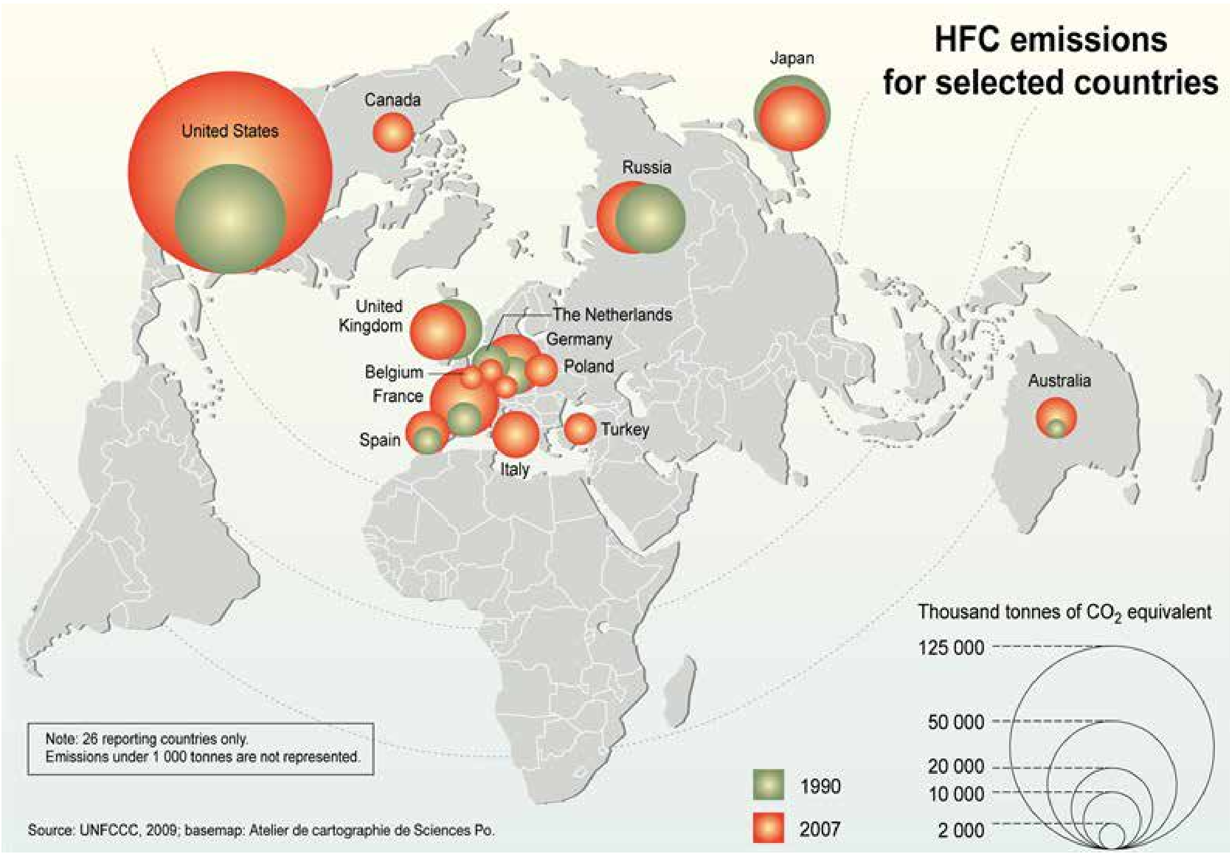
Europe.

Condensing units and packaged systems have the lowest level of commercialized low-GWP alternatives, however, these types of equipment can easily be avoided appropriate planning and using other types of equipment for which natural refrigerants are now available. Research is currently underway to prove and commercialize additional applications for natural refrigerants in supermarket refrigeration systems; over time, as demand for climate-friendly alternatives increases worldwide, so too will the range of alternatives and types of products available, as well as the number of suppliers that provide them.

Use of HFC-free equipment has the direct benefit of eliminating greenhouse gas emissions that result from leakage of HFC refrigerants, which can be 25% or more of the HFC charge annually. However, it is also important to consider the energy efficiency of these refrigeration systems as indirect greenhouse gas emissions from energy consumption can be greater than the emissions from direct emissions of HFCs over the lifetime of the refrigeration equipment. In the United States, mandatory and voluntary energy efficiency standards exist for both remote and self-contained refrigerated cases. These standards favor self-contained units using natural refrigerants (i.e., CO_2 and hydrocarbons) as they are as efficient and, in many cases, more efficient than comparable HFC-containing equipment.

I. HFC USE IS PROJECTED TO INCREASE EXPONENTIALLY UNLESS ACTION IS TAKEN; FORTUNATELY NATURAL REFRIGERANTS ARE INCREASINGLY AVAILABLE

FIGURE 1: GROWTH IN HFC EMISSIONS FOR SELECT COUNTRIES (1990-2007)[A]



HFC use in developed countries has increased dramatically during their phase-out of HCFCs.

[a]Cartographer/designer credit: Emmanuelle Bournay, UNEP/GRID-Arendal.

Supermarkets, convenience stores, distribution centers, warehouses, and refrigerated trucks all require refrigeration technologies to keep perishable products cool. These technologies have historically relied on synthetic refrigerants (i.e., CFCs and HCFCs) that both deplete the stratospheric ozone layer and contribute to climate change. Under the Montreal Protocol, these chemicals have been or are being phased-out in a global effort to restore the ozone layer. Under the doctrine of "common but differentiated responsibilities" in the Montreal Protocol, developed countries phase-out CFCs and HCFCs first with developing countries having binding commitments, but starting their phase-out years later. Under this scheme, 97 of the most potent ozone depleting substances (ODS) have been completely eliminated and now the countries of the world are phasing out HCFCs. Developed countries are heading to the 90% stage of their phase-out in 2015, while developing countries are just beginning their phase-out with a freeze of HCFC use and production in 2013 and the first 10% reduction in 2015.

Historically, 77% of the transitions in developed countries have been from HCFCs to a class of chemicals known as HFCs (hydroflourocarbons), which do not harm the ozone layer but are potent greenhouse gases (GHGs) with global warming potentials (GWPs) ranging from hundreds to thousands of times that of carbon dioxide (CO_2) (IPCC 1995). As a result of this transition and the entry of HFCs into the market as substitutes to HCFCs, global HFC emissions have been increasing significantly, as shown in Figure 1. HFCs today account for 3% of total annual GHG emissions in the United States and more than 1% of all global GHG emissions, and are growing by 8-9% annually. If steps are not taken to have developing countries transition directly from HCFCs to low-GWP technologies and developed countries do not take steps to curtail their use of HFCs, HFC emissions will reach 5.5-8.8 billion (giga-) tonnes of CO_2 equivalent ($GTCO_2eq$) by 2050, which will equal 9–19% of total global CO_2 emissions. (Velders et al. 2009).

It is estimated that HFC emissions from supermarket refrigeration equipment can account for almost 50% of a supermarket's total GHG emissions.

It is estimated that HFC emissions from supermarket refrigeration equipment can account for almost 50% of a normal supermarket's total GHG emissions (EPA 2011a). Emissions are high because equipment in this sector typically have large refrigerant charge sizes and high leak rates. For example, conventional rack systems, which are typically used in supermarkets, can have a refrigerant charge size of 2,000-5,000 pounds of HFCs (typically of HFC-404A or HFC-507A, which have GWPs of 3,900 and 3,985, respectively) and leak 25% per year or more (EPA 2005). Therefore, GHG emissions associated

GWPs of Common Refrigerants

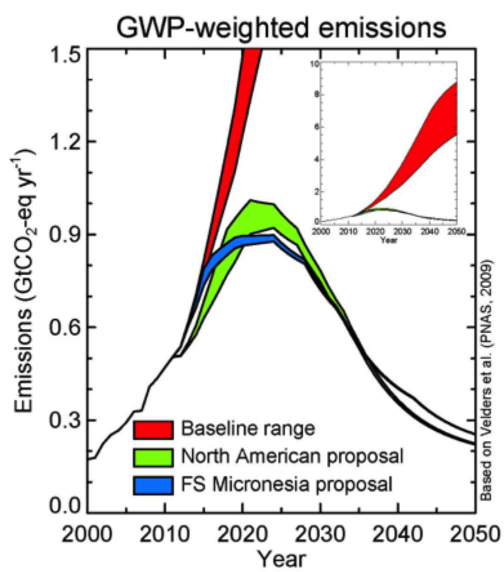
Refrigerant	GWP
Fluorinated Refrigerants	
CFC-12	*8,100*
R-502	*4,657*
R-507A	*3,985*
R-404A	*3,900*
HCFC-22	*1,500*
HFC-134a	*1,300*
HFO-1234yf	*4*
Natural Refrigerants	
Propane (R-290)	*3.3*
Isobutane (R-600a)	*3*
Propylene (R-1270)	*1.8*
CO2 (R-744)	*1*
Ammonia (R-717)	*0*

Sources: IPCC 1996 ; Calm et al. 2007 ; EPA 2010a.

Common Refrigerants have significantly higher GWP than natural refrigerants

with refrigerant leaks from just one supermarket over the commercial life of the refrigeration system could be equivalent to more than 2,000 $MTCO_2eq$, or the annual GHG emissions from roughly 350 passenger vehicles (EPA 2011b).

In the US, voluntary programs already exist that encourage supermarkets and other food retailers to minimize the use and emissions of HFC refrigerants. For example, the U.S. Environmental Protection Agency's GreenChill Partnership works with food retailers to encourage them to transition to environmentally friendlier refrigerants; lower refrigerant charge sizes; eliminate leaks; and adopt green refrigeration technologies and best environmental practices (EPA 2012). Additionally, in 2010, the Consumer Goods Forum (CGF)—a global industry network consisting of retailers, manufacturers, service providers and other stakeholders—agreed to "begin phasing-out HFC refrigerants as of 2015 and replace them with non-HFC refrigerants (natural refrigerant alternatives) where these are legally allowed and available for new purchases of point-of-sale units and large refrigeration installations" (CGF 2010). Even with these voluntary programs in place, with over 35,000 supermarkets in the United States, additional action is



The North American proposal and the Micronesian proposal to phase-down HFCs at the Montreal Protocol are similar; both decrease the cumulative (2013-2050) direct GWP-weighted emissions of HFCs to 22-24 $GtCO_2eq$, for a total of ~87 to 146 GtCO2eq in mitigation. This is equivalent to a reduction from projected annual emissions of 5.5 to 8.8 $GtCO_2eq$/yr in 2050 to less than ~0.3 $GtCO_2eq$/yr. (The reference scenarios for calculating the effects of the proposals are from Velders et al. (PNAS, 2009) without any updates.)

required to reduce emissions of these high-GWP GHGs. (FMI 2011).

Fortunately, a variety of climate-friendly alternatives are already available that would significantly reduce GHG emissions. Such alternatives include hydrocarbons,mainly propane (R-290), ammonia (R-717), and carbon dioxide (CO_2 or R-744). Other alternatives, such as isobutane (R-600a) propylene (R-1270) and not-in-kind alternatives are also likely to be commercialized and enter the market in the next few years. Additionally, new low-GWP HFCs, hydrofluoroolefins (HFOs), and other fluorine-containing fluids, and blends, are also likely to enter the market in the coming years; however, these chemicals are still categorized as HFCs and cannot be used to meet the CGF 2015 pledge.

The Environmental Investigation Agency (EIA), whose work focuses on raising awareness and advocating for climate-friendly alternatives to HFCs, hopes that this report will assist CGF members in planning how to meet their pledge to begin using HFC-free new equipment by 2015. To this end, this report aims to provide CGF members with practical guidance on how to implement their commitment to adopt HFC free technologies in the United States. The remainder of this report is organized a follows:

- Section II identifies commonly used refrigeration technologies and their applications;
- Section III discusses currently available low-GWP technologies that use HFC/HFO-free refrigerants;
- Section IV provides an overview of relevant energy efficiency standards in the U.S., which could potentially impact the availability of refrigerant alternatives on the U.S. market; and
- Appendix A provides a non-exhaustive list of equipment suppliers of HFC/HFO-free technologies.

II. OVERVIEW OF CURRENT MARKET AND THE VARIETY OF EQUIPMENT USED BY SUPERMARKETS AND OTHER RETAILERS

The retail food industry represents a variety of end-users including convenience stores, supermarkets, hypermarkets, warehouses, distribution centers, and transporters. These end-users rely heavily on refrigeration technologies to keep their products cool. Although all refrigeration technologies are based on the same fundamental principles, the system designs and equipment components used by each end-user differ depending on the application and varying refrigerated capacity needs.

SELF-CONTAINED UNITS

Self-contained units, also commonly referred to as stand-alone equipment or "plug-in" units, are fully integrated systems that consist of a case, evaporator, and condenser packaged into a single unit. Common types of self-contained units include vending machines, icemakers, ice-cream freezers, beverage cases, and plug-in display cases. These systems are commonly used in convenience stores and small markets, as well as in large supermarkets in spaces that are not easily accessible to the rack system refrigerant lines. The refrigeration capacity of self-contained units is relatively small, ranging from 1–10 kW (RTOC 2011). Consequently, the average charge size of these units is also small, equivalent to no more than a few kilograms of refrigerant (RTOC 2011).

REMOTE DISPLAY CASES/WALK-INS

Display cases and walk-ins that are not self-contained, are used in convenience stores and supermarkets to provide temporary storage for perishable foods prior to sale. To cool this equipment, display cases and walk-in units are connected to either a condensing unit or a rack system from which a refrigerant or heat transfer fluid is piped. Display cases are located on the sales floor while walk-in coolers are generally used for excess storage, although some may have one side open to the sales area. The specific design of the display cases and walk-ins used in a store is dictated by the type of food products being sold and spacing constraints (Armines 2009).

Due to differing characteristics of refrigerants and heat transfer fluids, the components within a display case or walk-in must be designed specifically for the refrigerant or heat transfer fluid that flows through it. The refrigerant type used by a condensing unit or rack system does not limit a store's ability to use a particular type of display case or walk-in; however, manufacturers of display cases and walk-ins must know in advance which refrigerant or heat transfer fluid will be used by a refrigeration system to ensure that all components employed are compatible.

PACKAGED SYSTEMS

Packaged systems are manufactured units that contain an evaporator and condensing unit on one frame that is mounted on a wall panel or roof of a refrigerated walk-in system. The evaporator is located inside the refrigerated space of a walk-in while the condensing unit, which is usually protected by weather-resistant housing, is located outside. Packaged systems are typically used to cool convenience store walk-ins or small refrigerated warehouses, which may rely on more than one unit in order to meet the refrigerated load requirements. Packaged units are relatively easy to install and are either pre-piped from the factory or equipped with quick-couple refrigeration line connections, resulting in a charge size that is roughly 10% smaller than comparable condensing unit systems (Bohn 2012). Compared to other refrigeration system types, packaged systems are considered to have lower capital costs, but may also have lower energy efficiency due to smaller evaporator and condenser surfaces, which are limited by space constraints.

CONDENSING UNITS

A condensing unit typically consists of one or two compressors, one condenser, and one receiver assembled into a condensing unit system, which is then linked to display cases or walk-ins through a piping network. These units are commonly found in convenience stores and are used in

In April 2011, Sprouts installed this Hill-PHOENIX Second Nature CO_2 Cascade System

supermarkets or distribution centers. The refrigeration capacity of condensing units is generally larger than self-contained units, ranging from 1–20 kW (RTOC 2011), and the average refrigerant charge size is also larger, ranging from 1–20 kg (EPA 2010a). Condensing units are easier to install and have lower upfront costs than most centralized rack systems but, may not be as energy efficient (RTOC 2011).

RACK SYSTEMS

The most common application of rack systems is in supermarkets and distribution centers.
Rack systems consist of pre-manufactured racks that contain multiple compressors and other components that are connected to a remote condenser and linked to display cases and walk-ins through a piping network. Independent racks of compressors can operate at different levels of evaporating temperatures (i.e., low temperature and medium temperature) to accommodate the cooling needs of both frozen goods and fresh produce.
Rack systems come in a variety of designs including:

• **Centralized Designs**: In a centralized design, all the compressor racks are located in a single machinery room. These systems, which are commonly referred to as multiplex systems, can have a cooling capacity of 20 kW to over 1 MW and can contain over 4,000 lbs of refrigerant due to the extensive piping network required to pipe the refrigerant throughout the store (RTOC 2011).

•**Distributed Designs**: A distributed design is characterized by the installation of the compressor racks in close proximity to the display cases, rather than in a central machinery room. Due to

Hill-PHOENIX ADVANSOR Transcritical refrigeration system the reduced need for piping, the overall refrigerant charge size can be 30-50% lower than centralized designs (EPA 2010a).

• **Indirect Designs**: Indirect designs are systems that use two fluids: a primary refrigerant and a secondary circulating fluid (i.e., the coolant). The primary refrigerant is used in the refrigerating system that is located entirely in the machinery room to cool a secondary fluid (e.g., glycol, CO_2) that is then circulated to the display cases and walk-ins, located throughout a store. Since the primary refrigerant is contained within the machinery room, indirect designs have low charge sizes, often 50-80% less than a comparable centralized design (RTOC 2011).

•**Cascade Designs**: Cascade designs consist of two independent refrigeration systems that share a common cascade heat exchanger. The heat exchanger acts as the low temperature refrigerant condenser and serves as the high temperature refrigerant evaporator. Each component of a cascade design uses a different refrigerant that is most suitable for the given temperature range.

CENTRAL PLANTS

Central plants are large refrigeration systems commonly used in large refrigerated warehouses or distribution centers where evaporators are suspended from the ceiling in the refrigerated space or mounted in penthouses on the roof of the building, and are coupled to multiple compressors and condensers. These systems are typically custom designed and may use either a direct or indirect design.

REFRIGERATED TRANSPORT SYSTEMS

Refrigerated trucks, railcars, and intermodal containers are essential to the successful transport of perishable goods and frozen products from the production facilities to the distribution centers to the sales floor. The technical requirements of transport refrigeration systems are extremely complex, as the equipment has to operate over a wide range of ambient temperatures and weather conditions, and must withstand frequent vibrations and shocks. Additionally, the system must be compact to maximize cargo space, and lightweight and efficient to reduce the energy and fuel needs of the vehicle (RTOC 2011). The refrigerant charge size of transport refrigeration equipment depends on the refrigeration capacity of the system as well as its specific application; on average, refrigerant charge sizes range from 4.5 to 7.5 kg, with the majority of equipment containing less than 6 kg (EPA 2011).

Truck Mounted Refrigerant System

III. AVAILABILITY OF ALTERNATIVES

Natural refrigerants are commercially available for most end uses and significant reductions in GHG emissions can be realized with their use instead of HFCs. These natural refrigerants include:

- **Hydrocarbons**, including isobutane, propane, and propylene, are less expensive than synthetic refrigerants; have low GWPs (typically <5); do not deplete the ozone layer; and are non-toxic, nearly odorless, and accomplish many of the specifications required for refrigerants. Hydrocarbons are flammable, which may restrict their use on some instances, but can be safely used in many refrigeration systems. In commercial refrigeration systems, propane is the most commonly used hydrocarbon.

- **Ammonia** is currently successfully used in large refrigeration systems. It has many advantages, including a high thermodynamic efficiency and the lowest GWP (<1) of all refrigerants suitable for large refrigeration systems. Yet, similar to hydrocarbons, ammonia is flammable. In addition, ammonia is toxic. Even so, when the appropriate safety precautions are applied, ammonia can safely be used as a refrigerant, and

Building Codes and Safety Standards

A variety of standard setting bodies—including Underwriters Laboratories (UL), the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), the American National Standards Institute (ANSI), and the International Institute of Refrigeration (IIR) — develop guidelines and safety standards specific to both equipment and buildings that are commonly adopted by national, state, and local authorities. Depending on the standards adopted by authorities in jurisdictions across the United States, there may be limitations set on the use of certain natural refrigerants due to flammability, toxicity, and/or design concerns. Particularly relevant standards to retail food operations include:

- ANSI/UL 471, Standard for Safety for Commercial Refrigerators and Freezers
- ANSI/UL 1995, Standard for Safety for Heating and Cooling Equipment
- ANSI/ASHRAE Standard 34, Designation and Safety Classification of Refrigerants
- ANSI/ASHRAE Standard 15, Safety Standard for Refrigeration Systems

Building codes and safety standards should be evaluated in the design stage of any new build or major remodeling to ensure that the selected alternative refrigerant technology can be used in the particular store location.

has been for more than one hundred years. Substantial innovation in the technology of ammonia systems has occurred during the past decade that have substantially reduced the charge size required. Supermarkets' refrigeration needs can be met with an ammonia system with 100 pounds of ammonia divided into 10 compartments, warehouse refrigeration systems can use as little as 250 pounds. Ammonia is also used in cascade systems with other refrigerants so that the ammonia is never in an occupied space.

• **Carbon dioxide** is a colorless, odorless, non-flammable gas that is being successfully used in commercial refrigeration systems. Although CO_2 is the largest contributor to global GHG emissions, it has a GWP of 1 and offers a climate-friendly alternative in refrigeration applications given that HFCs have GWPs hundreds or thousands of times higher. CO_2 rack systems are the most widely used alternative. CO_2 operates at significantly higher pressures than other refrigerants and therefore requires the use of stronger piping components and valves. While these design features make CO_2 systems initially more expensive, these design requirements make the volumetric refrigeration capacity of CO_2 much higher than that of HFC refrigerants, allowing for system designs with smaller volumes. The energy efficiency of CO_2 refrigeration systems is significantly impacted by the ambient air temperature, with higher energy efficiencies than HFC systems being achieved in cooler climates, but lower energy efficiencies in high ambient temperatures. CO_2 is used in

SECTOR	EXAMPLES OF ALTERNATIVES	INDUSTRIALIZED COUNTRIES	DEVELOPING COUNTRIES	GLOBAL TOTAL
INDUSTRIAL REFRIGERATION SYSTEM (A)	AMOINIA, CO_2, HC	92%	40%	65%
INDUSTRIAL AIR CONDITIONING SYSTEM	AMONIA, CO_2, HC	40%	15%	~25%
DOMESTIC REFRIGERATIORS (VABOR COMPRESSION CYCLE (B)	HC	51%	22%	36%
FOAM IN DOMESTIC REFRIGERATION	HC	66%	68%	67%
FOAM IN OTHER APPLIANCES (C)	HC	38%	<1%	28%
POLYURETHANE FOAMBOARDS AND PANELS (C)	HC	82%	21%	76%
FIRE PROTECTION SYSTEM (D)	WATER, FOAMS, DRY CHEMICALS, INERT GASES	-	-	75%
ASTHMA MEDICATION	DRY POWDER INHALERS	-	-	~33%
SOLVENTS (F)	AQUEOS, NO-CLEAN, ALCOHOLS, OTHERS	>90%	>80%	>80%

Sources: FTOC 2010; TEAP 2009ab; TEAP 2010a.
The percentages in this table refer to: (a) refrigerants used in new installations annually; (b) annual production of new equipment; (c) annual consumption of blowing agents; (d) usage of market; (e) annual medical doses; (f) market penetration in solvent applications.

transcritical systems and in cascade systems with other refrigerants to dramatically improve energy efficiency.

Natural refrigerants have been used for up to 150 years and are in use in a significant number of applications as indicated in the following table. Substantial research has gone on in the last ten years and is still going on to improve the technology that use these refrigerants so they can be used in other applications and other sectors, such as improving systems to reduce charge size and to ensure that these refrigerants can be safely used.
While each natural refrigerant has specific characteristics that are better suited for different types of technologies and uses, the available natural refrigerants provide CGF members and other supermarkets with numerous options to begin using HFC-Free equipment now. In the United States, use of alternative refrigerants is regulated by EPA's Significant New Alternatives Policy (SNAP) Program, as mandated by Section 612(c) of the Clean Air Act, which requires the EPA to publish a list of acceptable and unacceptable substitutes for ozone-depleting substances (ODS). Since ODS were historically used in all commercial refrigeration applications, the use of alternative refrigerants must be reviewed and deemed acceptable for use under SNAP. The following sections provide an overview of the natural refrigerants and associated system designs currently available in the United States and globally for each commercial refrigeration application.

SELF-CONTAINED UNITS

Although HFC-134a and HFC-404A continue to be the standard refrigerants used in most new self-contained units sold in the U.S. today, hydrocarbons (i.e., propane) and CO_2 are widely accepted alternatives for use in this equipment. Due to environmental concerns, appliance manufacturers and food producers in Europe, Asia, and Australia began using

Ben and Jerry's

Ben & Jerry's, the ice-cream manufacturer, petitioned the EPA to include three refrigerants used in commercial refrigeration systems to be included under the Significant New Alternatives Policy (SNAP) program, which evaluates substitute chemicals and technologies for ozone-depleting substances (ODS) under the provision of the Clean Air Act (CAA). The EPA approved the petition and listed propane, isobutene, and refrigerant-441A (a blend of hydrocarbons), as acceptable substitutes. The three acceptable substitutes are more energy efficient than HFCs in similar applications, and do not require recovery or recycling. Additionally, they have significantly lower GWP and do not damage the ozone layer.

Ben and Jerry's tested 2,000 hydrocarbon freezer units in the greater Boston, MA and Washington, D.C. areas between 2008 and 2011. Now that the EPA has approved the hydrocarbon freezers, the company plans to roll out the hydrocarbon freezers to replace their existing HFC freezers. Outside of the United States, in 2011, 70% of Ben & Jerry's freezers used hydrocarbons in place of HFCs. These units are 10% more energy efficient compared to the old HFC freezers and there is no significant upcharge in using Hydrocarbons. (Guevarra 2012).

propane (Refrigerant-290) as a replacement for HFC-404A and HFC-134a in refrigeration appliances as early as 2000 (Danfoss 2008; Unilever 2008). For example, Danone and Nestlé have several thousand coolers using hydrocarbon technology across a number of countries including Denmark, Mexico, and Germany (Shecco 2012).

Display cases and walk-ins that are not self-contained are connected to condensing units and rack systems through a piping network. The refrigerant or heat transfer fluid is cooled by the compressor in a condensing unit or rack system and then piped through the display cases and walk-ins to absorb and remove heat. Therefore, while the refrigerant used by the condensing unit or rack system will impact specific components within the display cases and walk-ins; compatibility concerns will not limit your refrigerant selection.

Propane is compatible with the most commonly used heat exchangers and materials, and has been found to perform about the same as or better than HFC-404A and HFC-134a in terms of energy efficiency (Danfoss 2008). Historically in the US, hydrocarbons in commercial refrigeration have been limited by safety concerns even though propane is a proven alternative and internationally recognized safety standards are available for the design and testing of appliances operating with flammable refrigerants. Recently, however, in December 2011, EPA's SNAP Program approved propane as an acceptable alternative for use in retail food stand-alone refrigerators and freezers for charge sizes less than 150 grams.

While hydrocarbons have been the manufacturers' preferred alternative refrigerant for use in certain applications, such as ice cream freezers and plug-in display cabinets, some have chosen to use CO_2 in other self-contained applications, such as vending machines. CO_2 vending machines have been under development since 2000, with units being sold in Japan as early as 2005 (Sanyo 2008). Global companies such as Coca-Cola and PepsiCo have also praised the CO_2 technology for vending machines, with Coca-Cola committing to 100% use of HFC-free refrigerants in new vending machines by 2015. As such, in 2010 Coca-Cola submitted a SNAP application to the U.S. EPA for the acceptable use of CO_2 vending machines; which was approved in August 2012. This approval will spur great expansion of the HFC free units, with hundreds of thousands of CO_2 vending machines already being used in Japan and Europe (BeyondHFCs 2010).

PACKAGED SYSTEMS

At this time, all packaged systems are only being manufactured using HFC refrigerants. Due to flammability concerns and internationally recognized safety standards, refrigerant charges are presently too large to allow for the use of a hydrocarbon refrigerant

in this application and CO_2 systems tend to be much more expensive as these are the cheapest refrigeration units. However, the use of packaged systems in retail food facilities is not essential and can be avoided by use of self-contained units, multiplex systems, or central plants, all of which have the current potential to use HFC-free technology. It is only a matter of time before alternatives become available for this use, however, for now, when planning conversions other equipment types should be used instead of packaged systems to avoid the use of HFC equipment.

CONDENSING UNITS

Similar to packaged systems, HFC-free alternative technologies are not currently available for condensing unit systems in the United States. Rather, HFC-404A and HFC-134a are the dominant refrigerants used in newly produced condensing units, with other refrigerant options also available (e.g., HFC-507, HFC-407C, HFC-410A, and other HFC blends) (RTOC 2011). While it is possible to use hydrocarbons in these systems, at this time, the average charge size of condensing units is significantly greater than 150g per system, which limits the transition to hydrocarbons without changes in standards, laws, and regulations. CO_2 is also a viable alternative for use in condensing units, although current cost could be a limiting factor until the market increases and the costs come down. EvCO_2 condensing unit systems are currently being used in Europe, and additional research is being conducted by companies such as Sanyo and Advansor to make them readily available in the United States in the near future (Admin 2009; R744 2012).

It is important to note that condensing units are often considered a low cost alternative option to using a rack system within a convenience store, supermarket, or distribution center. Until low-GWP condensing unit systems are available in the U.S., the use of HFC condensing units in retail food facilities is not essential and can be avoided, albeit at a higher cost. Instead, rack systems and self-contained units that rely on natural refrigerants can be utilized in place of condensing units to avoid the use of HFC equipment. A remote refrigeration system (either a rack system, or a condensing unit,

Overwaitea Food Group Installs Transcritical CO_2 System

Overwaitea Food Group, a company that currently operates more than 124 stores, chose to retrofit a former Olympic Village structure or 23,000 feet into a grocery store and include a Hill PHOENIX Advansor transcritical CO_2 booster refrigeration system. This system utilizes CO_2 as the only refrigerant covering both medium temperature and low temperature loads. The CO_2 allows the system to operate under much higher pressures than HFC-based systems, and is much less expensive than alternative HFC refrigerants; $2 per pound compared to $20 per pound.

Although, the CO_2 system operates at a much higher pressure than conventional systems, the system installed by Overwaitea eliminates the risk of pressure-related system breakdowns by using pressure-reducing valves. These valves reduce the pressure of the system to as low a level as would be observed under an HFC-based system. Overwaitea chose to install a back-up auxiliary condensing unit on a back-up generator in case of power failure. This smaller unit cools the CO_2 and keeps the pressure low to prevent CO_2 loss. Overall, this system allows Overwaitea to use a “100 percent HFC-free” system and greatly reduce their direct and indirect greenhouse gas emissions. (R744 2012c).

linked to cases) is more energy efficient than a series of individual self-contained units, each with its own compressor, and so equipment costs, operating costs, and energy consumption should be considered in selecting alternative systems and refrigerants and may over the life of the system make up for the higher up-front costs.

RACK SYSTEMS

HFC-404A and HFC-507 historically have been the most commonly used refrigerants in centralized designs in the United States, with HFC-407A and HFC-407C in use (RTOC 2011; EPA 2010a). However, currently many new technologies use natural refrigerants in place of HFCs in large rack systems that are typically found in convenience stores, supermarkets, and hypermarkets. CO_2, which was approved by EPA's SNAP Program in 2009, is already commonly used as a secondary or low temperature fluid in either indirect or cascade designs in Europe and is increasingly being used in the United States and Canada.

In recent years, transcritical designs use CO_2 as primary refrigerant. The CO_2 transcritical technology was first developed in 1998 and has been used in retail food applications, largely in central and northern Europe, since 2006 (Shecco 2012). CO_2 transcritial systems are similar to traditional centralized designs but must operate at high pressures to accommodate the low critical temperature of CO_2 (GTZ Proklima 2008). As a result, special controls and component specifications must be incorporated into the system design, which often result in higher upfront costs. At the same time, CO_2 systems rely on smaller diameter pipes, which can lower installation costs. Additionally, as CO_2 transcritical systems operate most efficiently in cooler climates, other design modifications will need to be considered for use in regions with high ambient temperatures. Although research is being conducted to improve the efficiency of these systems at higher ambient temperatures, for now, use of these systems is most widely accepted in areas where the maximum ambient temperature remains below 88°F or 31°C, which is where they perform best (ACHR News 2010).

It is estimated that today over 1,300 CO_2 transcritical systems are currently in operation in Europe in addition to a handful of systems that have been installed in Canada

U.S. Supermarkets are Switching to HFC-Free Cascade Systems

SUPERVALU

Supervalu is committed to sustainability in refrigeration, and was a founding member of the GreenChill partnership, having installed numerous pieces of HFC-free equipment in their stores. Their latest natural refrigerant installation, at their Carpinteria, CA Albertson's store uses two main systems, an ammonia primary system and a CO_2 medium temperature cascade to a DX system on the low temperature side. Only 250 lbs of ammonia are needed in this system, and the ammonia is all located in an outdoor enclosure. The CO_2 system has one vessel that contains liquid, which is pumped to the low, and medium temperature display cases and walk-in cabinets. The reduction in total equivalent warming impact of this system, which measures recovery losses, leakage, and energy consumption, is 84% compared to a HFC system, and has been operating "like a champ" says Richard Heath, Director of Energy Innovations and Projects for Supervalu. (Supervalu 2012). Supervalu also installed 45 skylights, LED lighting, and glass refrigeration doors, allowing the store to use 30% less energy than a traditional store of its size. Because of these efficiency measures, the U.S. Department of Energy highlighted this store as a part of the President's Better Buildings Challenge. (Key News Staff 2012).

(Shecco 2012). However, in the United States, there are currently no CO_2 transcritical systems in operation, as the widely adopted standard, ANSI/UL 1995, does not directly address this technology and consequently limits its use. Efforts are underway to revise this standard to address the use of CO_2 transcritical systems and thereby permit its market adoption. In the meantime, it is possible for local authorities to make exceptions to their building codes to allow for the implementation of pilot projects, several of which are being explored at this time. In addition, American refrigeration equipment supplier, Hill PHOENIX, recently acquired Advansor—a Denmark-based company that specializes in transcritical CO_2 technologies; thus, more CO_2 transcritical systems will begin to be used in the U.S. (Hill PHOENIX 2011). Specifically, in Canada, Sobeys have already installed 36 CO_2 transcritical systems, and in the US, Hannaford Bros., Fresh & Easy Neighborhood Market and Whole Foods Market are looking into implementing transcritical systems in the near future.

Other options for applying natural refrigerants to rack systems include the use of hydrocarbons, ammonia, and/or CO_2 as a primary refrigerant in a cascade or indirect design. Use of hydrocarbons in these applications is somewhat limited due to the safety concerns associated with charge sizes greater than 150 g. Furthermore, hydrocarbons are not currently approved as an acceptable substitute for large retail food refrigeration systems under EPA's SNAP Program. However, this technology is being used by some food retailers in Europe. (Shecco 2012). In the United States, companies are choosing other alternatives such as ammonia and CO_2 in a cascade design. Ammonia/CO_2 cascade plants are already being used in refrigerated warehouses and distribution centers in the United States (as discussed in more detail below), and are estimated to represent up to 5% of the retail food market in other developed countries (Shecco 2012). Additionally, unlike CO_2 transcritical systems, ammonia/CO_2 cascade systems are suitable for use in warmer climates. Although toxicity and liability concerns historically have hindered wide scale use of ammonia in the United States, due to the significant improvements in system design, reduced charge sizes and better safety features, several retail chains are currently using ammonia cascade system pilot projects. Furthermore, ammonia has already been deemed acceptable under EPA's SNAP Program as an alternative for use as a primary refrigerant

Hybrid Systems Allow for Transitioning to HFC-Free Stores

Sprouts

- Sprouts has been focused on being an "environmentally conscious neighbor and grocer," joined EPA's GreenChill partnership in May of 2012 and has since earned eight GreenChill Store Awards. In April of 2011, Sprouts installed a Hill PHOENIX Second Nature CO_2 Cascade System, which utilizes two independent refrigeration systems that share a common cascade heat exchanger. The lower-cascade system uses CO_2 while the upper-cascade is a 70% reduced charge HFC system. Additionally, the entire HFC refrigerant is confined to the machine room to reduce leakage and increase a stores ability to detect leaks. Besides CO_2 being cheaper than HFCs, and the system being more energy efficient, CO_2 also requires smaller piping lines that use 50% less copper, which reduces installation costs. (Hill Phoenix 2011b).

Sams Club

- In 2006, Hill PHEONIX and Sam's Club partnered to install the first Second Nature Technology. The Savannah, Georgia store replaced HFC-404a with propylene glycol and 65% water as the secondary fluid. By using this technology, they could reduce the initial HFC-404a charge by 34%. This switch will eliminate 6,448 tonnes of CO_2e emissions over ten years. The store also uses CO_2 as the secondary heat transfer fluid, further reducing the amount of HFC used in the store. (Powel 2006).

Fresh & Easy

- Fresh & Easy is committed to helping the environment, and builds stores that on average use 30% less energy than typical supermarkets. In 2012, Fresh & Easy opened a store in Folsom, California that featured a Hill PHOENIX Second Nature system that uses glycol for medium temperature fixtures and walk-ins and CO_2 for low temperature fixtures and walk-ins. The cascade system is comprised of multiple compact chiller modules where each is a standalone factory-assembled refrigeration system. This set-up allows the store to use just 70 pounds of refrigerant, instead of the 3,500 pounds used by a typical supermarket in the U.S. The reduction in refrigerant allows for a sustainable zero leak rate, which led the EPA to award the store a GreenChill Platinum Award. Fresh & Easy has the most currently GreenChill Certified stores in the United States. (Green Retail Decisions 2012).

Wegmans

- Wegmans installed a CO_2 refrigeration system in their Potsville, PA distribution center in 2012 after having success with the technology in their Woodmore, MD store. (Wegmans 2012). The system uses liquid CO_2 as a secondary refrigerant that is circulated through pipes inside the freezers, where it absorbs heat. This system allows the primary refrigerant, HFC-404a, to be contained in a machinery room and only half as much is needed. (R744 2011).

Natural Refrigerants Used In Distribution Centers

TESCO opened a distribution center in 2009 to service its Fresh and Easy stores near Riverside, California. The Distribution Center is a 53,000 square foot building uses a two-stage pumped recirculated ammonia system that services a multitude of 30-40°F processing rooms via 53 evaporators, make up air units, and 1,500 horsepower of screw compressors. This system is also designed to cool -30°F spiral blast freezers and other processing equipment. (C & L Refrigeration 2012).

In 2009, Target opened a 430,000 square-foot distribution center in Cedar Falls, Iowa. (RTK Network 2012). This distribution center includes 400,000 square feet of cold storage that is cooled by an ammonia refrigeration system installed by Ryan Companies, USA. They also have an ammonia distribution center in Lake City, Florida. (Ryan Companies US 2011).

WAL★MART

Wal-Mart opened its first sustainable distribution centre in Alberta, Canada on November 10, 2010. The facility is 400,000 square feet and serves as a fresh and frozen food hub for 104 Wal-Mart stores in Western Canada. Their goal with this facility was to highlight the immediate business returns available in investing in sustainable practices. Wal-Mart operates 321 stores in Canada and serves more than one million customers a day. The choice of ammonia which has a zero global warming potential, is natural occurring, and does not cause ozone depletion was an integral part of Wal-Mart Canada's sustainability program. Using ammonia in the system has resulted in 33% more energy efficient than a comparable HFC system, and the company has estimated that the reduced energy use will help avoid an estimated $2 million in costs over five years. (Walmart 2010).

in secondary loop commercial applications. This approval along with its use globally proves that ammonia can be safely and effectively used in supermarket applications. Currently in the U.S., the Defense Commissary Agency is considering using an ammonia/CO_2 cascade system at the Lackland Air Force Base Commissary in Texas, which has an 8% energy savings, reduces leakage by 25% and elimates HFCs. In addition to ammonia, several companies in the United States are using proplylene glycol as the secondary refrigerant and CO_2 as the primary refrigerant in cascade systems. For example, Ahold USA's Giant Landover's Arlington store is using CO_2 for its primary, low-temperature refrigeration and propylene glycol as a secondary refrigerant for medium-temperature refrigeration and thereby reduces its GHG emissions by over 172 metric tonnes of CO_2 equivalents per year. (Ahold 2011).

In the U.S., some retailers have begun the transition to HFC-free refrigeration by installing hybrid systems. These systems use a natural refrigerant, usually CO_2, and a smaller charge of HFC. Currently, there are three main types of hybrid systems being used; Cascade Low Temp CO_2 & Medium Temp Glycol, Secondary Low Temp CO_2 & Modular Medium Temp Glycol, and Cascade Low Temp CO_2 & Secondary Medium Temp CO_2. (EPA 2012). These systems can reduce the HFC charge from 30-80%, and can be a good first step to reducing emissions in current stores, although these hybrid systems do not satisfy the Consumer Goods Forum Pledge for new store builds.

CENTRAL PLANTS

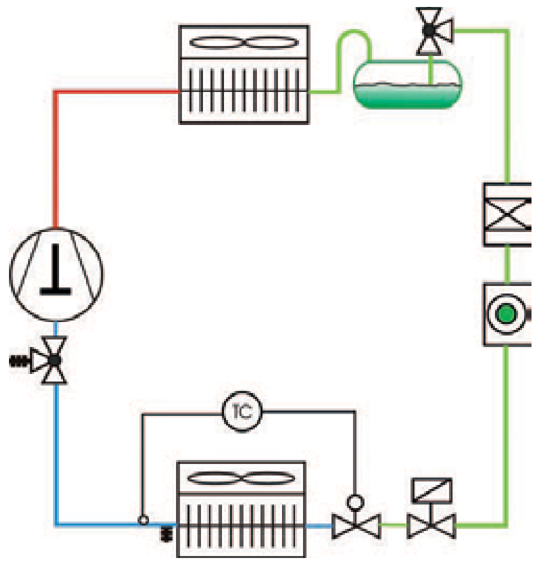
While smaller facilities may

generally have used HFC technologies, ammonia, a SNAP-approved substitute for use in cold storage warehouses, is currently the most commonly used refrigerant in large central plants, including refrigerated warehouses and distribution centers. Ammonia has been used in industrial applications for more than 150 years due to its energy efficiency and low operating costs. Although ammonia has a global warming potential of zero, it is both toxic and flammable; therefore, special safety precautions must be implemented for its safe use.

To minimize the risks associated with the use of ammonia, new systems are being designed to use smaller charge sizes and are currently being installed using carbon dioxide (CO_2) as the low temperature refrigerant in an ammonia/CO_2 cascade design (M&M Refrigeration 2012). In these systems, CO_2 circulates through the evaporator coils in the refrigerated section of the facility while the ammonia portion of the system is contained within the machine room and evaporative condenser so the ammonia is never in the human occupied portion of the facilities. The total charge of ammonia in an ammonia/CO_2 plant is greatly reduced compared to a full ammonia plant. Additionally, ammonia/CO_2 plants have lower capital costs and insurance risks, as well as higher energy efficiencies.

REFRIGERATED TRANSPORT SYSTEMS

The predominate technology used in all transport refrigeration equipment in the US today, is



Refrigerant System Layout from EPA Green Chill Report, ProKlima Int., Good Practices in Refrigeration

the vapor compression cycle that uses either HFC-134a or HFC-404A as the refrigerant (RTOC 2011). However, both CO_2 and hydrocarbons, specifically propane, are being used in a limited but growing number of refrigerated transport fleets in Europe (Shecco 2012). In particular, propane is under development and testing for use in refrigerated trucks and home delivery vans in the United Kingdom and Germany (RTOC 2011). Although propane has not yet been approved as an acceptable substitute by EPA's SNAP Program, the ongoing trials in Europe suggest that there is potential to increase the use of propane in transport refrigeration applications (RTOC 2011).

CO_2 is also currently being tested for use in refrigerated trucks and trailers, as well as high-efficiency intermodal containers (EPA 2011c). Cryogenic systems that use liquid CO_2 as a cryogenic fluid are already being used in trucks and trailers in a number of EU countries. Cryogenic systems cool cargo by injecting stored liquid CO_2 (or nitrogen) into the cargo space or an evaporator; the CO_2 is then recaptured or released into the atmosphere without being recycled into the system (EPA 2011c). This is different from a CO_2 compression system, which is a continuous system in which the refrigerant is recycled through the evaporator and condenser. In 2011, the world's first intermodal refrigeration system designed using a CO_2 compression system was introduced (Carrier Transicold 2011). Demonstration units are currently being tested in various locations worldwide, including the United States and Singapore (EPA 2011). Cryogenic systems using recaptured liquid CO_2 are acceptable substitutes for ODS in transport refrigeration equipment under EPA's SNAP Program; however, use of CO_2 as a substitute for HFCs in intermodal containers has not yet been approved.

Highlights of HFC-Free Supermarkets Worldwide

Many supermarket chains around the world are leading the transition away from harmful HFC refrigerants to natural refrigerant alternatives. The following are just a few examples of how supermarkets are making this transition:

Drakes

- In 2007, Drakes became the first chain to install a CO_2 transcritical system in the southern hemisphere at its Foodland store in South Australia (Eurammon 2010).

Pick'n Pay

- Two Pick'n Pay stores in South Africa are now using CO_2/ammonia cascade system technologies (Shecco 2012).

Sobeys

- This Canada-based chain implemented their first CO_2 transcritical system in 2009 and now has installed more than 30 of these systems, which are now their national standard (Sobeys 2011).

Tesco

- Tesco was the first chain in the UK to open a store using solely natural refrigerants for its cooling needs. This was achieved with the help of Johnson Controls through the installation of a CO_2/HC cascade system (Eurammon 2010). Tesco was also the first to install a CO_2 transcritical system in the UK in 2006 (Shecco 2012).

Waitrose

- The UK-based company has successfully installed propane refrigeration systems in numerous stores with plans to continue to install this technology in all new and retrofitted stores (Greenpeace 2010).

AEON

- The Japan-based company, and one of the largest retailers in Asia, has been a leader in HFC-free refrigeration, pledging to use natural refrigerants in 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 from 2015 onwards in compliance with the Consumer Goods Forum pledge. They have also pledged to progressively convert 3,500 stores to natural refrigerants. (R744 2012b)

Natural Refrigerant Technologies Are Available to Allow All Supermarkets to Become HFC-Free.

As described below, natural refrigerants are readily available for use in the vast majority of retail food applications. Table 3 below summarizes the status of use and SNAP-approval of each alternative refrigerant by equipment type, which shows in what applications each of these refrigerants is most useful at present.

TABLE 3: OVERVIEW OF AVAILABLE ALTERNATIVES AND SNAP APPROVAL BY EQUIPMENT TYPE

EQUIPMENT TYPE	HYDROCARBONS	CO_2	AMMONIA
SELF-CONTAINED UNITS: VENDING MACHINES	• NOT SNAP-APPROVED • BEING USED OUTSIDE THE U.S.	• SNAP APPROVAL PENDING; COMMONLY USED IN JAPAN AND EU COUNTRIES	• NOT SNAP-APPROVED; NO KNOWN USE
SELF-CONTAINED UNITS: REACH-IN CASES	• SNAP-APPROVED (PROPANE ONLY) (12/20/11) • GAINING MARKET SHARE IN THE U.S. • COMMONLY USED OUTSIDE THE U.S.	• NOT SNAP-APPROVED; NO KNOWN USE	• NOT SNAP-APPROVED; NO KNOWN USE
PACKAGED SYSTEMS	• NOT SNAP-APPROVED • NO KNOWN USE	• SNAP-APPROVED (9/30/09) • NO KNOWN USE DUE TO COST BARRIERS	• SNAP-APPROVED (9/5/96) • NO KNOWN USE DUE TO COST BARRIERS
CONDENSING UNITS	• NOT SNAP-APPROVED • NO KNOWN USE	• SNAP-APPROVED (9/30/09) • BEING USED OUTSIDE THE U.S. BUT GENERALLY CONSIDERED COST PROHIBITIVE IN THE U.S.	• SNAP-APPROVED (9/5/96) • USED HISTORICALLY IN INDUSTRIAL APPLICATIONS BUT NOT CURRENTLY USED COMMERCIALLY
RACK SYSTEMS	• NOT SNAP-APPROVED • BEING USED WITH SECONDARY LOOPS OR IN CASCADE DESIGNS IN EU	• SNAP-APPROVED (9/30/09) • USED IN SECONDARY LOOPS OR CASCADE DESIGNS WITH HFCS IN THE U.S. • NON-HFC CO_2 SYSTEMS IN USE IN EU, AUSTRALIA, SOUTH AMERICA	• SNAP-APPROVED (9/5/96) WITH A SECONDARY LOOP • NO KNOWN USE IN U.S. • IN USE IN EU
CENTRAL PLANTS	• NOT SNAP-APPROVED • NO KNOWN USE	• SNAP-APPROVED (9/30/09) • USED IN CASCADE DESIGNS WITH AMMONIA IN THE U.S. AND OTHER COUNTRIES	• SNAP-APPROVED (9/5/96) • COMMONLY USED IN THE U.S. AND GLOBALLY
REFRIGERATED TRANSPORT SYSTEMS	• NOT SNAP-APPROVED • BEING TRIALED IN EUROPE	• SNAP-APPROVED (12/6/99) FOR USE IN A CRYOGENIC SYSTEM USING RECAPTURED LIQUID CO_2 • NO KNOWN USE	• NOT SNAP-APPROVED • NO KNOWN USE

IV. OVERVIEW OF RELEVANT ENERGY EFFICIENCY STANDARDS

PHOTO: Carl Reeverts, EIA

In addition to the direct leakage of refrigerants, the operation of retail food equipment contributes to emissions of GHGs indirectly through the consumption of energy. Hydrocarbons, which are the most commonly used natural refrigerant in self-contained units, have shown to be more efficient and use less energy than their HFC-refrigerant counterparts (Danfoss 2008). Similarly, vending machines using CO_2 have also been found to be more energy efficient than equipment that uses HFCs (Sanyo 2008). For larger systems (i.e., rack systems and central plants), the natural refrigerants of choice are ammonia and CO_2. Both refrigerants, used in the proper application have proven to be energy efficient when compared with HFC systems.

In the United States, various energy efficiency standards exist at both the state and federal level that pertain to retail refrigeration equipment. While state programs date back to the 1970s, the federal appliance energy efficiency standards were not established by the U.S. Department of Energy (DOE) until 1987. Today, states have the option to implement their own efficiency standards for products not yet covered by federal law; however, once a federal standard becomes effective, the state standard no longer applies (EPA 2006). In addition to these requirements, commercial refrigeration equipment may also be manufactured to meet voluntary energy efficiency product labeling standards, such as the U.S. Environmental Protection Agency and the U.S. Department of Energy's ENERGY STAR program. The following section summarizes the specific type of equipment relevant to each standard as well as the potential impact these standards may have on the availability of such equipment being placed on the U.S. market with natural refrigerants.

DEPARTMENT OF ENERGY'S COMMERCIAL EQUIPMENT STANDARDS

The U.S. Department of Energy's (DOE) Appliances and Commercial Equipment Standards Program develops test procedures and minimum efficiency standards for residential appliances and commercial equipment. Standards have been developed for a variety of equipment types including vending machines and other self-contained and remote commercial refrigerators and freezers. By law, DOE must upgrade standards to the maximum level of energy efficiency that is technically feasible and economically justified (DOE 2010). These federal appliance efficiency standards preempt any state standards; if a state desires to maintain a more stringent standard, it may petition the DOE for a waiver allowing it to do so (C2ES 2012). A summary of the standards relevant to this report is provided below:

• **Vending Machines**: The Energy Conservation Standards for Refrigerated Bottled or Canned Beverage Vending Machines (10 CFR Part 431) is a performance standard, meaning it identifies maximum daily energy consumption levels (kWh) based on the equipment class and refrigerated volume.

• **Commercial Refrigeration Equipment**: The Energy Conservation Program for Commercial and Industrial Equipment (10 CFR Part 431) is applicable to commercial ice-cream freezers; self-contained commercial refrigerators, commercial freezers, and commercial refrigerator-freezers without doors; and remote condensing commercial refrigerators, commercial freezers, and commercial refrigerator-freezers. Similar to vending machines, this regulation sets a performance standard based on the equipment class and total display area of a case. For the technical analysis conducted in support of the rulemaking, DOE used HFC refrigerants as the basis,

Energy Efficiency Programs in North American Supermarkets

Delhaize

The International retailer Delhaize led an aggressive energy reduction campaign in their US brands Sweetbay and Food Lion in 2010. By putting doors on refrigerated cases and upgrading to LED lighting, they were able to achieve a 1.4% reduction per square meter of sales area group-wide. These activates saved Sweetbay $3.12 million and Food Lion $1.84 million in 2010. (Delhaize 2012).

Ahold

Globally, Ahold has committed to a goal of reducing its CO_2 per square meter of sales by 20% by 2015. To do this Ahold's USA stores implemented several energy saving initiatives that are expected to reduce energy usage by 23 million kWh per year. These initiatives include installing new low-energy glass doors on reach-in freezers, installing LED track lighting fixtures storewide, and reducing leaks from refrigerants. Currently they have leakage monitoring systems installed in 243 stores with plans to install this technology in 111 more. Installation of the LED track lighting alone has produced reductions of 2.9 million Kwh per year, and the new glass doors have reduced energy usage by 2.3 million Kwh per year. (Ahold 2011).

Loblaw

The Canadian retailer, Loblaw, is committed to reducing greenhouse gas emissions and has been focusing on ways to reduce energy consumption, refrigerant leaks, waste, and transportation emissions. In 2011, Loblaw's converted 112 stores to fluorescent lighting, and replaced lighting in refrigeration and freezer doors to light-emitting diodes (LED). At the Maple Leaf Gardens store, Loblaws used a CO_2 refrigeration system that makes use of the energy reclaimed from the refrigeration system to heat the underground parking garage. It is through initiatives like this and leak checking initiatives that Loblaw's was able to reduce the total amount of refrigerant leaks by 9.7% in 2011. (Loblaw 2011).

acknowledging that alternative refrigerants such as hydrocarbons, ammonia, and CO_2 are used more widely outside the United States. Therefore, such alternatives were not considered in developing the energy efficiency standards. DOE believes that the small self-contained equipment covered in this rulemaking could possibly use hydrocarbon refrigerants if they contain less than 3 pounds of refrigerant and are certified for the U.S. market (DOE 2009). Now that CO_2 has been approved for use in vending machines, DOE will need to revise its standards.

• **Walk-In Coolers & Freezers** (WICF): The Energy Conservation Standards for WICF (10 CFR Part 431) is applicable to large, insulated refrigerated spaces with access door(s) large enough for people to enter, with a total chilled storage area of less than 3,000 square feet. Currently, WICF need to meet various specifications related to doors, insulation, motors, and lights; however, DOE is currently in the process of developing a performance-based standard for this equipment (DOE 2011).

For these and all other federal appliance efficiency standards, the DOE outlines test procedures that manufacturers must use to certify that their appliances meet the standards. These standards do not limit the use of natural refrigerants in retail food establishments, or specifically, self-contained units. Furthermore, DOE's standards do not apply to condensing units or compressor racks, which consume the energy load associated with refrigerants; therefore, manufacturers of remote display cases do not need to consider refrigerant type when designing their equipment to meet these standards.

Fresh & Easy, Folsom, CA Grocery Store, Installed LED lighting in the refrigerators and added doors that reduced energy use by 50%.

CALIFORNIA'S APPLIANCE EFFICIENCY REGULATIONS

Similar to DOE's standards, California's appliance efficiency regulations consists of performance-based standards that apply to both self-contained and remote commercial refrigerators and freezers (CEC 2010). These regulations are set by the California Energy Commission (CEC) and apply to new products sold in California, except those sold wholesale in California for final retail sale outside the state. As already discussed, hydrocarbons and CO_2—the natural refrigerants currently used in self-contained units—have been shown to be more efficient than HFCs in these applications. Therefore, these standards should not limit the use of HFC alternatives in this type of commercial equipment. Additionally, remote display cases do not consume the energy load associated with the refrigerant that runs through it and, therefore, the refrigerant type does not need to be a consideration in meeting the efficiency standard.

Like California, other states have also set their own appliance efficiency standards for reach-in and walk-in refrigerators and freezers. As previously noted, once federal standards become effective, they preempt state standards unless a waiver is granted for states to maintain a more stringent standard (C2ES 2012).

CALIFORNIA'S PROPOSED BUILDING ENERGY EFFICIENCY STANDARDS

Under Title 24 of the California Code of Regulations, the CEC regulates energy consumption through energy efficiency standards of residential and nonresidential buildings. These standards apply to newly constructed buildings and major renovations to existing buildings. Currently, standards are being drafted for supermarket refrigeration systems in stores with a sales area greater than 8,000 square feet. The new standards are to become effective

HFC Insulating Foams Used in Retail Food Equipment

Proper insulation of refrigerated spaces is critical in order to minimize energy use and keep food products at the desired temperature. HFC blowing agents, namely HFC-134a, HFC-245fa, and HFC-365mfc/227ea, are commonly used in insulating foam contained in self-contained units, display cases, walk-ins, refrigerated warehouses, and refrigerated trucks. HFC blowing agents are emitted during product/equipment manufacture, use, disposal, and even following disposal (e.g., in landfills), if foam is not properly recovered and destroyed.

Although insulating foams are not the focus of this report, it is important to recognize the environmental impact they can have and promote the transition to climate-friendly alternatives. Globally, a wide variety of alternatives are available, including hydrocarbons (e.g., cyclopentane, and cyclopentane/isopentane blends) and CO_2/water systems. Methyl formate is also gaining increasing acceptance. An estimated 20% of all domestic refrigeration units made in the U.S. contain foam blown with these alternatives (EPA 2010b). Even though HFC blowing agents are still widely used, CGF members should be able to seek out HFC-free foam in order to fully meet their CGF pledge. It is expected that the percentage of HFC-foam in the US will continue to rise.

in 2014. In developing these proposed requirements, the CEC worked jointly with the California Air Resources Board (CARB) to consider the climate impacts associated with refrigerant use and emissions. The draft code language includes the use of a CO_2 cascade system or indirect cooling system (in stores with a sales area greater than 20,000 square feet) as a Reach Code measure. Reach Codes are voluntary standards but are often mandated for adoption by local jurisdictions (California Utilities Statewide Codes and Standards Team 2011). While indirect cooling systems still commonly rely on HFCs, the inclusion of natural refrigerants in California's Title 24 Reach Code would clearly signal a move away from HFCs.

ENERGY STAR PROGRAM REQUIREMENTS

ENERGY STAR is a joint program of the U.S. EPA and DOE aimed at saving money and protecting the environment through energy efficient products and practices.

Specifically, it is a voluntary program that establishes labeling standards for energy-efficient products to make it easy for consumers to identify and purchase such products without sacrificing performance. Commercial refrigeration equipment types that are eligible for ENERGY STAR qualification include both self-contained and remote refrigerators and freezers. Similar to DOE's commercial equipment standards and California's appliance efficiency regulations, ENERGY STAR specifications require that commercial refrigeration products meet maximum daily energy consumptions levels (kWh); however, ENERGY STAR specifications set even higher energy efficiency levels. Typically, only a small fraction of the products on the market will qualify at any given time.

The ENERGY STAR commercial refrigerator qualified product list as of February 16, 2012 included models that virtually all use R-404A or HFC-134a refrigerant; only one reach-in cabinet model was included that uses propane. The small number of ENERGY STAR qualified appliances using propane is not surprising, given that propane was only recently approved as acceptable under EPA's SNAP Program as an alternative for use in self-contained units, thus only a limited number of U.S. suppliers currently offer propane products. However, as more manufacturers transition to this technology, the number of ENERGY STAR qualified products can be expected to increase.

V. CONCLUSION: HFC-FREE SUPERMARKETS ARE FEASIBLE TODAY

PHOTO: Emma Clark, EIA International

Given the great risk that HFCs gases pose to the global climate, low-GWP alternative refrigeration technologies are rapidly being developed, proven, and commercialized. Already, there are numerous proven HFC-free technologies available for use in the United States. Specifically, self-contained units, rack systems, and central plant systems that rely on hydrocarbons, carbon dioxide, ammonia, or combinations of these refrigerants are being manufactured and sold on the U.S. market. The continued market penetration of these alternatives is expected as many of the technologies are already commonly used internationally and continue to gain industry support.

Moreover, as these technologies gain acceptance and increased market share internationally, additional alternatives will be submitted by equipment manufacturers for EPA SNAP-approval to clear the way for use in the United States.

Additionally, as these technologies become more widely adopted, their associated costs will decrease and servicing infrastructure will expand. Highly efficient product designs are available using natural refrigerants for the types of equipment for which energy efficiency standards currently exist in the United States. In particular, self-contained units—the only equipment-type containing refrigerant that is covered by mandatory standards—are currently available with hydrocarbon and CO_2 refrigerants.

Together, proper planning and proven technologies using alternative refrigerants will support CGF members' efforts to meet their pledge to use only HFC-free equipment in new refrigeration applications by 2015 and allow other supermarket chains to follow their example. Given the urgent need to reduce greenhouse gas emissions associated with retail food refrigeration equipment, there is no need to wait until 2015; now is the time to begin the transition to climate-friendly alternatives to HFCs.

Useful Websites

Ammonia21
www.ammonia21.com/

Beyond HFCs
www.beyondhfcs.org/

California's Appliance Efficiency Program
www.energy.ca.gov/appliances/

California's Building Energy Efficiency Standards
www.energy.ca.gov/title24/

ENERGY STAR
www.energystar.gov

Hydrocarbons21
http://hydrocarbons21.com/

R744.com
www.r744.com/

Shecco
www.shecco.com/

Refrigerants Naturally!
www.refrigerantsnaturally.com/

U.S. DOE's Commercial Equipment Standards
www1.eere.energy.gov/buildings/appliance_standards/commercial_products.html

U.S. EPA Fact Sheets on Low-GWP Alternatives
http://www.epa.gov/ozone/intpol/mpagreement.html

U.S. EPA's SNAP Program
www.epa.gov/ozone/snap/

U.S. EPA's GreenChill Partnership
www.epa.gov/greenchill/

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Appendix A. Non-Exhaustive List of Non-HFC United States System Suppliers

SUPPLIER NAME	COMPANY WEBSITE	SELF-CONTAINED UNITS	RACK SYSTEMS	CENTRAL PLANT SYSTEMS	TRANSPORT REFRIGERATION SYSTEMS
AHT	WWW.AHT.AT/EN/HOME/HOME.ASP	HC			
AMERICAN INDUSTRIAL REFRIGERATION	AIREFRIG.COM/			AMMONIA	
CARRIER TRANSICOLD	WWW.TRANSICOLD.CARRIER.COM				CO_2
FOGEL GROUP	WWW.FOGEL-GROUP.COM/EN	HC			
FRIGOGLASS	WWW.FRIGOGLASS.COM/	HC/CO_2			
GEA-FES	WWW.GEAFES.COM/EN-US/PAGES/DEFAULT.ASPX			AMMONIA/CO2	
HAIER	WWW.HAIERAMERICA.COM/	HC			
HILL PHOENIX	WWW.HILLPHOENIX.COM		AMMONIA/CO2	AMMONIA/CO2	
INDUSTRIAL REFRIGERA-TION SYSTEMS	WWW.INDUSTRIALREFRIGERATIONSYSTEMS.COM/			AMMONIA	
JOHNSON CONTROLS	WWW.JOHNSONCONTROLS.COM/PUBLISH/US/EN.HTML			AMMONIA	
KYSOR WARREN	WWW.KYSORWARREN.COM		AMMONIA/CO_2		
M&M REFRIGERATION	MMREFRIGERATION.COM			AMMONIA/CO_2	
METALFRIO SOLUTIONS	WWW.METALFRIO.COM	HC			
SANYO ELECTRIC	US.SANYO.COM	HC/CO_2			
THERMOKING	WWW.THERMOKING.COM/TK/INDEX.ASP				CO_2
TRJ REFRIGERATION	WWW.TRJ-INC.COM/			AMMONIA	
U.S. COLD STORAGE COMPANY	WWW.USCOLD.COM			AMMONIA/CO_2	
ZERO ZONE	WWW.ZERO-ZONE.COM/			AMMONIA	

Many equipment manufacturers offer refrigeration systems in the United States that are HFC-free. The table above provides an indicative, non-exhaustive list of system suppliers in the U.S. for each type of readily available non-HFC equipment discussed in Section III. The type of refrigerant available for use in each type of equipment by each supplier is also noted, as applicable. It should be noted that there are many other suppliers that offer HFC-free commercial refrigeration equipment outside the U.S.

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