TRANSITIONING TO LOW-GWP ALTERNATIVES
in Commercial Refrigeration

Background

This fact sheet provides current information on low global warming potential (GWP)[1] alternative refrigerants to high-GWP hydrofluorocarbons (HFCs) for use in commercial refrigeration equipment. HFCs are powerful greenhouse gases (GHGs) with GWPs hundreds to thousands of times more potent per pound than carbon dioxide (CO_2); however, more low-GWP alternatives are becoming available.

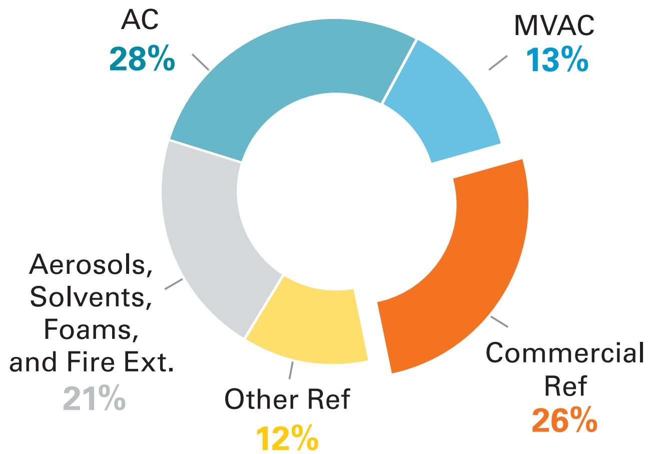
Globally, approximately 80% of HFCs are emitted in the refrigeration, air conditioning (AC), and motor vehicle AC (MVAC) sectors, with the remainder accounted for by the foam-blowing, aerosols, fire suppression, and solvents sectors. While developed nations have historically accounted for the majority of global HFC emissions, total HFC emissions in developing nations are projected to quadruple by 2030. This rapidly increasing rate of HFC emissions is largely driven by the increased demand for refrigeration and AC, particularly in the tropical climates of much of the developing world, and the transition away from ozone depleting substances (ODS).

Commercial Refrigeration Equipment

Commercial refrigeration equipment is used to store and display chilled or frozen goods for customer purchase at food retail and service establishments (e.g., supermarkets, convenience stores, commissaries, hospitals, restaurants, and cafeterias). Equipment used in these applications can generally be categorized into three main system types: (1) stand-alone or self-contained refrigeration systems, (2) remote condensing unit systems, or (3) multiplex rack systems (i.e., supermarket systems). Descriptions of each of these system types are provided on the following pages, followed by Table 1, which lists the typical capacity, refrigerant charge, and annual operational leak rate for each system type.

HFC emissions from commercial refrigeration equipment will account for approximately 26% of global HFC emissions in 2020 (see Figure 1). HFC refrigerant emissions from commercial refrigeration are released to the atmosphere throughout the lifecycle of equipment—i.e., during equipment manufacture, installation, operation, and at end-of-life.

Figure 1. Global HFC Emissions in 2020 by Sector



Global HFC Emissions: 1,084 MMT CO_2 Eq.
Global HFC Emissions in Commercial Ref: 286 MMT CO_2 Eq.

Source: Estimates based on U.S. EPA (2013).

[1] GWP is a measure of a substance's climate warming impact compared to CO_2.

Stand-alone or Self-contained Refrigeration Systems

Stand-alone or self-contained refrigeration systems house all refrigeration components (e.g., evaporator, cooling coil, compressor, and condenser) within their structure. These types of systems cover a wide range of equipment types, including:

- **Reach-in refrigerators, freezers,** and **beverage coolers,** which are characterized by door type (e.g., transparent, solid, or no door) and orientation (e.g., horizontal, semi-vertical, or vertical).

Source: U.S. DOE (2009)

- **Ice makers,** which are classified by nominal capacity and harvest rate (i.e., the weight of ice produced per 24 hours); characteristics vary depending on the type of ice produced (e.g., cubes, flakes, and nuggets).
- **Food-service equipment,** such as preparation tables with a refrigerated countertop, worktop tables with a commercial refrigerator or freezer, and buffet tables that maintain food temperatures for serving.

Source: U.S. DOE (2009)

- **Water coolers,** which are characterized by a small refrigeration capacity and provide chilled water for drinking. They may or may not feature detachable containers of water.
- **Packaged walk-in food storage equipment,** which consist of a large insulated box with a packaged refrigeration system (i.e., an evaporator and condensing unit in one frame) mounted on the roof or wall of a walk-in system. This type of equipment has a larger capacity compared to reach-in equipment and beverage coolers.

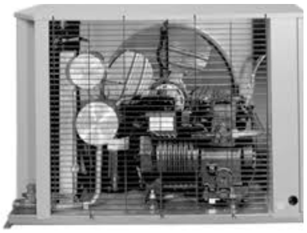
Source: U.S. DOE (2009)

- **Refrigerated vending machines,** which keep products, such as drinks in cans or bottles, and perishable food items (e.g., prepared sandwiches) cool. This type of equipment can be fully-cooled (i.e., all items within the machines are refrigerated) or zone cooled (i.e., only a portion of the machine is refrigerated).
- **Refrigerated food processing and dispensing equipment,** which dispense and often process a variety of food and beverage products. The three main product categories include soft serve/ice cream machines, chilled beverage dispensers, and frozen beverage dispensers. The equipment can be self-contained or can be connected via piping to a dedicated condensing unit located elsewhere.

Source: Taylor Company (2015)

Remote Condensing Unit Systems

Condensing unit systems typically consist of one or two compressors, one condenser, and one receiver assembled into a modular system. The systems are connected to display cases or walk-in refrigerators and freezers through a refrigerant piping network. In most cases, the unit is located on the building rooftop or outside at ground level. Unlike self-contained equipment, remote condensing units are not pre-charged and plug-in ready. They must be assembled and charged on-site before going into operation.



Source: U.S. DOE (2009); Master-Bilt (2014)

Multiplex Rack Systems (Supermarket Systems)

Multiplex rack systems, sometimes referred to as supermarket systems, are commonly used to cool remote walk-in refrigerators and freezers and display cases in supermarkets and hypermarkets. They are custom designed and complex, consisting of racks of multiple compressors and other components that are connected to a remote condenser. The system is linked to multiple display cases through a piping network. The condensers are usually remotely located, such as on the roof above the machinery room. As described on the following page, they come in a variety of designs.

Source: Hillphoenix (2013)

- **Centralized direct expansion (DX),** where refrigerant is circulated directly from a central machinery room to the display cases in the sales area.
- **Distributed,** where smaller compressor racks are located throughout the store in close proximity to the display cases (e.g., on the roof above the cases, behind a nearby wall); distributed designs typically have lower charge sizes than centralized designs due to the reduced need for refrigerant piping.
- **Cascade,** which consists of two independent refrigeration circuits that use two different refrigerants but share a common heat exchanger.
- **Indirect/secondary loop,** where a primary refrigerant is used in the central machinery room to cool a secondary heat transfer fluid, which is circulated to the display cases in the sales area; indirect systems typically have lower charge sizes than centralized designs because the primary refrigerant is contained in the machinery room.
- **Transcritical CO_2,** where CO_2 is used as the primary refrigerant, evaporating in the subcritical region and rejecting heat at temperatures above the critical point in a gas cooler instead of a condenser.

Table 1. Typical Commercial Refrigeration Equipment Characteristics

Equipment	Capacity (kW)	Refrigerant Charge (kg)	Annual Operational Leak Rate (%)
Stand-Alone or Self-Contained Systems	0.1 to 1	0.1 to 2	< 1%
Remote Condensing Unit Systems	0.1 to 20	1 to 20	5 to 20%
Multiplex Rack Systems	40 to > 200	20 to 3,000	10 to 35%

Sources: IPCC (2005); TEAP (2013); TEAP (2014); UNEP (2015a); UNEP (2015b)

Improved Servicing and End-of-Life Practices

Refrigerant emissions from commercial refrigeration equipment can occur throughout the equipment's lifecycle. System leaks during operation are generally caused by the inevitable wear on a refrigeration system over time (e.g., due to vibration, thermal expansion and contraction, and corrosion), as well as poor design and improper installation, servicing, and/or maintenance practices, including poor brazing techniques, improperly tightened fittings, missing valve caps and seals, use of incompatible materials, improper support of copper tubing, and inadequate leak diagnosis and repair.

During servicing events and end-of-life disposal, refrigerant leaks are generally caused by improper refrigerant recovery techniques. The extent of refrigerant losses will depend on various factors including the existence of and compliance with refrigerant recovery laws, the technical efficiency of refrigerant recovery equipment, and the proficiency of technicians' service practices.

Improvements in the technologies and practices adopted by manufacturers, technicians, and equipment owners, the introduction of alternative refrigerants and technologies, implementation of refrigerant recovery laws and standards, and market/policy drivers that provide financial incentives for recovery, may help to offset most HFC refrigerant emissions from commercial refrigeration equipment.

HFC Alternatives and Market Trends

Global demand for commercial refrigeration equipment is forecasted to increase dramatically. Many commercial refrigeration systems in use contain ozone depleting refrigerants chlorofluorocarbon (CFC)-12, hydrochlorofluorocarbon (HCFC)-22, and R-502, which are being phased out globally under the *Montreal Protocol*. Many new units sold today contain HFCs and HFC blends, namely HFC-134a, R-404A, and R-507A, with GWP values of 1,430, 3,920, and 3,985, respectively. A number of lower-GWP alternative refrigerants are available and currently in use or under development for use in commercial refrigeration.

EPA's Significant New Alternatives Policy (SNAP) program ensures the smooth transition to alternatives that pose lower overall risk to human health and the environment. Under SNAP, EPA has listed several alternatives as acceptable for use in retail food refrigeration equipment, including: propane (R-290), carbon dioxide (CO_2, R-744), and ammonia (R-717). SNAP rulemakings published in July 2015 and December 2016 list up to 33 refrigerants and refrigerant blends as unacceptable in newly manufactured and retrofitted supermarket systems (starting in 2017), remote condensing units (starting in 2018), stand-alone units (starting in 2019 and 2020), and refrigerated food processing and dispensing equipment (starting in 2021) (see Table 2).

Table 2: Changes in SNAP Listing Status for Refrigerants in Commercial Refrigeration

End-Use	Final Rule Change of Status Date*
Supermarket Systems (Retrofitted)	July 20, 2016
Supermarket Systems (New)	January 1, 2017
Remote Condensing Units (Retrofitted)	July 20, 2016
Remote Condensing Units (New)	January 1, 2018
Stand-Alone Retail Food Refrigeration Equipment (Retrofitted)	July 20, 2016
Stand-Alone Retail Food Refrigeration Equipment (New)	January 1, 2019/January 1, 2020
Vending Machines (Retrofitted)	July 20, 2016
Vending Machines (New)	January 1, 2019
Refrigerated Food Processing and Dispensing Equipment (New)	January 1, 2021

*Please refer to the SNAP website for more detailed information about unacceptable refrigerants and more details on when the changes in listing status will become effective.

These alternatives and their potential applications are described in detail below.

Table 3. GWPs and Global Use Status of Alternatives for Commercial Refrigeration[a]

Refrigerant	GWP[b]	Stand-alone Systems[c,d]	Remote Condensing Units[c,d]	Multiplex Rack Systems[c,d]
R-449A	1,400	◆+[e]	◆+	◆+
R-449B	1,412	◆+[e]	◆+	◆+
R-448A	1,387	◆+[e]	◆+	◆+
HFC-32	675		☐	☐
R-513A	630	☐+	◆+	◆+
R-450A	601	☐+	◆+	◆+
R-447A	583		☐	
R-446A	461		☐	
R-451B	164	☐	☐	☐
R-451A	149	☐	☐	☐
HFO-1234ze(E)	6	☐	☐	
R-441A	<5	◆+[f]	☐	☐
HFO-1234yf	4	☐	☐	
R-600a (isobutane)	3	◆+[f]	◆	
R-290 (propane)	3	◆+[g]	◆	☐
R-744 (CO_2)	1	◆+	◆+	◆+
R-717 (ammonia)	0			◆+

[a] ◆ = Available now; ☐ = Under Development; + = U.S. EPA SNAP-approved

[b] GWP values are from IPCC Fourth Assessment Report (2007) and U.S. EPA (2015c).

[c] UNEP (2015b).

[d] TEAP (2014).

[e] U.S. EPA SNAP-approved for low-temperature stand-alone eqiupment, commercial ice machines, and refrigerated food processing and dispensing equipment only.

[f] U.S. EPA SNAP-approved subject to use conditions for stand-alone refrigerators, freezers, and reach-in coolers and refrigerated vending machines only.

[g] U.S. EPA SNAP-approved subject to use conditions for stand-alone equipment, self-contained commercial ice machines, water coolers, and refrigerated vending machines only.

R-290 (Propane), R-600a (Isobutane), and Hydrocarbon Blends (e.g., R-441A)

Stand-alone Systems

- Several global manufacturers aim to replace their HFC beverage coolers with R-290 within the next five years
- R-290 beverage coolers and stand-alone display cases are expected to be more efficient than HFC-134a beverage coolers and R-404A stand-alone display cases
- Self-contained R-290 units are being used in some supermarkets in lieu of a conventional rack system
- Several UL and IEC standards limit the charge size of flammable refrigerants to 150 grams in stand-alone systems, including: UL 451 (vending machines), UL 471 (commercial refrigerators and freezers), UL 563 (ice makers), and IEC 60335-2-89 (commercial refrigerating appliances)

Remote Condensing Units

- Direct expansion remote condensing units using up to 1.4 kilograms of R-290 and R-600a are commercially available in Europe from major manufacturers
- Indirect remote condensing units using R-290 are in use in Europe with charge sizes varying from 1 to 20 kg, most of them on the lower charge side
- Hydrocarbon condensing unit systems can be up to 15% more expensive to purchase and install than HFC systems

Multiplex Rack Systems

- R-290 in a cascade design used in North America and Europe; first installation in the United States is being market tested by a major food retailer
- Demonstration projects have been carried out in Denmark using R-290 in a cascade design

Carbon Dioxide (CO_2, R-744)

Stand-alone Systems

- One of the world's largest beverage companies has installed more than 1.7 million beverage coolers and vending machines using R-744
- Field tests indicate that units use less energy compared to HFC units at moderate ambient temperatures

Remote Condensing Units

- Remote condensing units using R-744 are commercially available in Northern Europe and Japan with low, but increasing, market share
- R-744 remote condensing units require a double-stage design in warm climates; this barrier is expected to be overcome soon

Multiplex Rack Systems

- Efficiency and performance expected to be better than HFC rack systems in low to moderate ambient temperature regions
- R-744 cascade systems are available worldwide; for example, more than 50 systems are operating in Brazil
- Secondary loop systems that use CO_2 as a secondary fluid are also gaining market share
- Denmark, Germany, Canada, Japan, and the United Kingdom dominate the market for transcritical CO_2 rack systems with more than 3,000 installations; global sales are expected to increase more than five-fold by 2020 with significant growth in the United States and China

Ammonia (R-717)

Multiplex Rack Systems

- Used in cascade systems in the high-temperature refrigerant circuit, alongside R-744, which is used in the low-temperature refrigerant circuit
- R-717 cascade systems are available worldwide, including in Luxembourg, Switzerland, South Africa, and the United States

HFC/HFO Blends

Stand-alone Systems

- R-450A, R-451A, R-451B, and R-513A are being considered for use in medium-temperature applications

Remote Condensing Units

- R-446A, R-447A, R-450A, and R-513A are being considered for use in remote condensing units
- R-451A and R-451B are being considered for use in medium-temperature applications

Multiplex Rack Systems

- R-448A and R-449A are being used in supermarkets in Europe; a Dutch retailer is converting refrigeration systems in 200 supermarkets to R-449A
- R-448A, R-449A, and R-449B are beginning to be used in supermarkets in the United States
- R-450A trials have been conducted in various supermarkets in Europe, including Spain, and is now commercially available in Europe
- R-451A and R-451B are being considered for use in medium-temperature applications

HFO-1234yf, HFO-1234ze(E), and other HFOs

Stand-alone Systems and Remote Condensing Units

- Use is under development

HFC-32

Remote Condensing Units

- Use is under development

Multiplex Rack Systems

- Beginning to be used in centralized systems for medium-temperature refrigeration
- Under development for use in centralized systems for low-temperature refrigeration

Case Study: Transcritical CO_2 Systems in Turkey

Transcritical CO_2 systems are among the emerging design technologies for natural refrigerant multiplex rack systems. In 2012, Carrefour Group installed Turkey's first transcritical CO_2 system in Istanbul. The transcritical CO_2 system replaced a conventional R-404A multiplex rack system in a local hypermarket. The system delivers refrigerant to low-temperature and medium-temperature equipment using steel pipes, which are required due to the system's high operating pressure. Benefits of the transcritical system include the elimination of an HFC refrigerant, a similar cooling performance compared to R-404A systems in similar climatic conditions, a significant reduction in the potential for system leaks due to fewer brazed joints, and increased energy efficiency.

Challenges associated with the transcritical system included the need for additional safety considerations due to the high operating pressures, along with advanced design solutions for operating in hot climates, including an adiabatic air cooling system. According to Carrefour Group, there is also a need for more qualified service contractors who can address the needs of the CO_2 refrigeration market. There is currently limited expertise for service and maintenance in Istanbul. Despite these challenges, the system is expected to reduce refrigerant leaks by 75% due to improved pipe fittings and increase energy efficiency by approximately 15%.

Future Outlook

Together, the suite of known alternative chemicals, new technologies, as well as better process and handling practices, can significantly reduce HFC use in both the near and long term. Many countries are transitioning to lower-GWP alternatives in commercial refrigeration applications while satisfying the various international energy efficiency, safety, and environmental standards. The equipment manufacturers and chemical producers for the commercial refrigeration industry are continuing to work on developing new alternatives that can be marketed worldwide. Although much work remains to fully develop and adopt some of these low-GWP alternatives, and some unknowns still remain, the affected industries have proven through the ODS phaseout that they can move quickly to develop low-GWP alternatives that protect the environment.

References

The Air Conditioning, Heating and Refrigeration NEWS (ACHR News). 2015. "Transcritical CO_2 Refrigeration Market Worth $30.7 Billion by 2020." September 2015. Available online at: http://www.achrnews.com/articles/130595-transcritical-co2-refrigeration-market-worth-307-billion-by-2020

Christensen, K. and Bertilsen, P. 2004. "Refrigeration systems in supermarkets with propane and CO_2 – energy consumption and economy." Available online at: https://www.scribd.com/document/205784571/Refrigeration-Systems-in-Superm-CO2-Propane

The Consumer Goods Forum (CGF). 2016. "Refrigeration: Commitments & Achievements of CGF Members." Available online at: http://www.theconsumergoodsforum.com/files/Publications/201601-CGF-Refrigeration-Booklet-Final.pdf

Environmental Investigation Agency (EIA). 2012. "U.S. Market Study of HFC-Free Technologies for the Supermarket-Retail Refrigeration Sector." June 2012. Available online at: http://eia-global.org/news-media/hfc-free-technologies-are-available-in-the-us-market-for-the-supermarket-re

Freedonia Group. 2015. "World Commercial Refrigeration Equipment." October 2014. Available online at: http://www.freedoniagroup.com/brochure/32xx/3225smwe.pdf

Hillphoenix. 2013. Parallel Racks. Available online at: http://www.hillphoenix.com/refrigeration-systems/parallel-racks/

ICF International. 2015. "Market Characterization of the U.S. Motor Vehicle Air Conditioning Industry, U.S. Foams Industry, U.S. Aerosols Industry, and U.S. Commercial Refrigeration Industry." Docket ID: EPA-HQ-OAR-2014-0198-0241. Prepared for U.S. Environmental Protection Agency's Stratospheric Protection Division. July 2015. Available online at: http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OAR-2014-0198-0241

Intergovernmental Panel on Climate Change (IPCC)/ Technical and Economical Assessment Panel (TEAP). 2005. "Safeguarding the Ozone Layer and the Global Climate System: Issues Related to Hydrofluorocarbons and Perfluorocarbons, Chapter 4: Refrigeration." Devotta, S., Sicars, S. Available online at: http://www.ipcc.ch/pdf/special-reports/sroc/sroc04.pdf

Intergovernmental Panel on Climate Change (IPCC). 2007. "Climate Change 2007: The Physical Science Basis." Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (Eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. September 2007. Available online at: http://www.ipcc.ch/publications_and_data/ar4/wg1/en/contents.html

Jacob, B., Azar, A., Neksa, P. 2006. "Performance of CO_2-Refrigeration (R-744) in Commercial Cold Drink Equipment." Available online at: http://www.ammonia21.com/files/pdf_219.pdf

Master-Bilt. 2014. Refrigeration Systems. Available online at: http://master-bilt.com/products/refrigeration-systems

Taylor Company. 2015. "Model C723 Soft Serve Freezer." Available online at: http://www.taylor-company.com/en/product-detail/model-c723

Technology and Economic Assessment Panel (TEAP). 2013. "Decision XXIV/7 Task Force Report: Additional Information to Alternatives on ODS." September 2013. Available online at: http://ozone.unep.org/Assessment_Panels/TEAP/Reports/TEAP_Reports/TEAP_TaskForce%20XXIV-7-September2013.pdf

Technology and Economic Assessment Panel (TEAP). 2014. "Decision XXV/5 Task Force Report: Additional Information to Alternatives on ODS (Final Report)." October 2014. Available online at: http://42functions.org/Assessment_Panels/TEAP/Reports/TEAP_Reports/TEAP_Task%20Force%20XXV5-October2014.pdf

Technology and Economic Assessment Panel (TEAP). 2015. "Decision XXVI/9 Task Force Report: Additional Information on Alternatives to Ozone-Depleting Substances." June 2015. Available online at: http://42functions.net/Assessment_Panels/TEAP/Reports/TEAP_Reports/TEAP_Task-Force-XXVI-9_Report-June-2015.pdf

United Nations Environment Programme (UNEP). 2014. "Low-GWP Alternatives in Commercial Refrigeration: Propane, CO_2 and HFO Case Studies." Spring 2014. Available online at: http://www.ccacoalition.org/en/resources/low-gwp-alternatives-commercial-refrigeration-propane-co2-and-hfo-case-studies

United Nations Environment Programme (UNEP). 2015a. "2014 Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee (RTOC)." February 2015. Available online at: http://ozone.unep.org/sites/ozone/files/documents/RTOC-Assessment-Report-2014.pdf

United Nations Environment Programme (UNEP). 2015b. "Fact Sheet 4: Commercial Refrigeration." UNEP Ozone Secretariat Workshop on HFC management: Technical Issues. Bangkok, 20 and 21 April 2015. Available online at: http://ozone.unep.org/sites/ozone/files/Meeting_Documents/HFCs/FS_4_Commercial_Refrigeration_Oct_2015.pdf

United Nations Industrial Development Organization (UNIDO) and shecco SPRL. 2013. "Guide 2013: Natural Solutions for Developing Countries." Available online at: http://publication.shecco.com/upload/file/org/1384313761689368_442684.pdf

United States Department of Energy (U.S. DOE). 2009. "Energy Savings Potential and R&D Opportunities for Commercial Refrigeration." September 2009. Prepared by Navigant Consulting. Available online at: http://apps1.eere.energy.gov/buildings/publications/pdfs/corporate/commercial_refrig_report_10-09.pdf

United States Environmental Protection Agency (U.S. EPA). 2011. "GreenChill Best Practices Guideline: Commercial Refrigeration Leak Prevention & Repairs." EPA 430-B-11-001. May 2011. Available online at: http://www.epa.gov/sites/production/files/documents/leakpreventionrepairguidelines.pdf

United States Environmental Protection Agency (U.S. EPA). 2013. "Global Mitigation of Non-CO_2 Greenhouse Gases: 2010-2030." EPA Report 430-R-13-011. September 2013. Available online at: https://www3.epa.gov/climatechange/Downloads/EPAactivities/MAC_Report_2013.pdf

United States Environmental Protection Agency (U.S. EPA). 2014. "GreenChill Advanced Refrigeration." December 2014. Available online at: https://www.epa.gov/greenchill/advanced-refrigeration

United States Environmental Protection Agency (U.S. EPA). 2015a. "Protection of Stratospheric Ozone: Determination 30 for Significant New Alternatives Policy (SNAP) Program." Determination of Acceptability. 80 FR 42053. July 2015. Available online at: http://www.gpo.gov/fdsys/pkg/FR-2015-07-16/pdf/2015-17469.pdf

United States Environmental Protection Agency (U.S. EPA). 2015b. "Protection of Stratospheric Ozone: Change of Listing Status for Certain Substitutes under the Significant New Alternatives Policy (SNAP) Program." Final Rule. 80 FR 42869. July 2015. Available online at: https://www.federalregister.gov/articles/2015/07/20/2015-17066/protection-of-stratospheric-ozone-change-of-listing-status-for-certain-substitutes-under-the

United States Environmental Protection Agency (U.S. EPA). 2015c. "Significant New Alternatives Policy (SNAP) Substitutes by Sector: Retail Food Refrigeration." Available online at: http://www.epa.gov/snap/retail-food-refrigeration

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

SNAP
SIGNIFICANT • NEW • ALTERNATIVES • POLICY