ENGINEERING
TOMORROW

Momentum Grows for **Refrigerants** with **Low Global Warming Potential**

Developments in using CO_2 for commercial refrigeration, decarbonizing the electric grid, and shifting electricity consumption by employing demand-response and thermal -storage technologies are contributing to a low-GWP future.

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Fluctuating environmental policies in the U.S. tend to obscure the fact that the transition toward refrigerants with a **low global warming potential (GWP)** continues. HVACR manufacturers, researchers and facility owners worldwide are **making significant progress** thanks to consistent public policies, but also from recent development of **proven technologies.**

Technologically, it's worth looking at recent moves away from refrigerants with high GWPs — like HFC-134a and HFC-404A — and toward low-GWP formulations, like natural hydrocarbons and hydrofluoroolefins (HFOs) with GWPs below 5. The HFOs have a low GWP because they break down in the atmosphere over a few days. Furthermore, HFOs together with HFCs form low-GWP hybrids that have GWP ratings below 150.

Innovation is the key that is unlocking the potential of the new refrigerants to create a low-GWP future. It is evident with R290 semi-plug units becoming more widely accepted, and important developments that include: Utilizing the thermodynamics of CO_2 refrigerant — specifically, its expansion energy and heating properties — to make CO_2 even more feasible for commercial refrigeration; the ongoing decarbonizing of the electric power supply; and, boosting flexibility in electric consumption with demand response and thermal storage technologies.

These developments are driving forward the adoption of low-GWP refrigerants in food and commercial refrigeration today.

Moving Concerns from Ozone Depleting to Global Warming Refrigerants

Following the success of the 1987 Montreal Protocol enabling the transitions from high to low ozone depletion potential (ODP) refrigerants, the 2016 Kigali Amendment focused on transitioning from high- to low-GWP gases. The total impact of a cooling system on the environment can be measured through its Life Cycle Climate Performance (LCCP).

The LCCP number summarizes the direct impact of the production, usage and leakage of refrigerants, and the indirect emission caused by the production of the system (such as materials) and electricity consumed by the system. Under the 2016 Kigali Amendment, 197 countries committed to cut the production and consumption of hydrofluorocarbon (HFC) refrigerants, most of which have GWPs ranging from 675 to 3,985. In cutting HFC consumption by over 80 percent by 2047, the Kigali Amendment aimed to prevent a modeled 0.5°C increase in global temperature by the end of the century.

The U.S. has not yet ratified the Kigali Amendment, which went into effect Jan. 1, 2019. Nevertheless, the U.S. Environmental Protection Agency (EPA) — through its 2016 Significant New Alternative Program (SNAP) rules — had banned the use of high-GWP HFCs in many types of commercial refrigeration systems, including supermarket and commercial food equipment. Subsequent lawsuits resulted in the EPA withdrawing the HFC ban in 2018.

Nevertheless, several states are developing HFC phasedown rules. California has adopted EPA SNAP Rules 20 and 21 and will be implementing GWP limit-based rules in the future. Other states are seeking to implement those EPA SNAP rules, as well. Seven states have proposed or enacted 13 laws, regulations or plans since 2018.

Fluctuating policies pose a problem for HVACR equipment manufacturers. Regulatory consistency would help smooth the transition from high- to low-GWP refrigerants, which has been technologically challenging.

In the earlier transition from high to low ODP refrigerants, manufacturers could generally use a "drop-in" approach — that is, simply replacing one refrigerant for another after modifying seals and other minor components. That is not always possible with the switch to low-GWP refrigerants. Natural refrigerants, such as ammonia and CO_2, operate with different parameters compared to HFCs and require specially designed system components. Other natural refrigerants, such as propane, use components similar to those employed with HFCs, but special safety precautions need to be taken.

Depending on corporate goals and local regulations, manufacturers and end-users worldwide are adopting low-GWP-refrigerant systems employing various technological innovations.

In the US, if the phasedown of HFCs proceeds state-by-state without a nationwide program, HFCs will remain cheap and available and their price steady and low. In 2018 and 2019, HFC consumption continued to drop, low-GWP refrigerant prices started to stabilize, and the conversion to low-GWP solutions gained momentum.

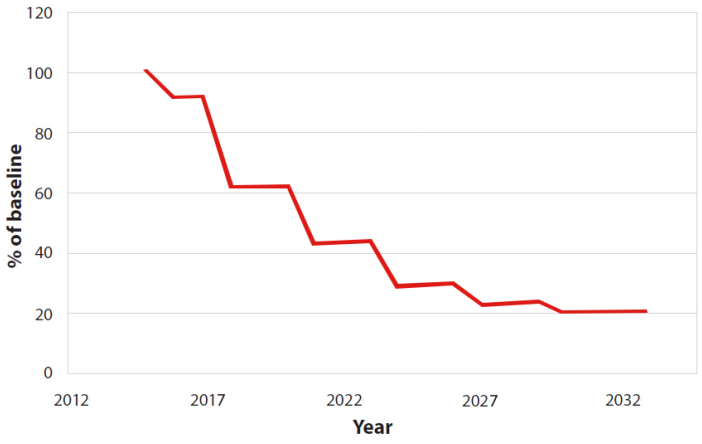


Figure 1: The European Union's HFC consumption phase down.

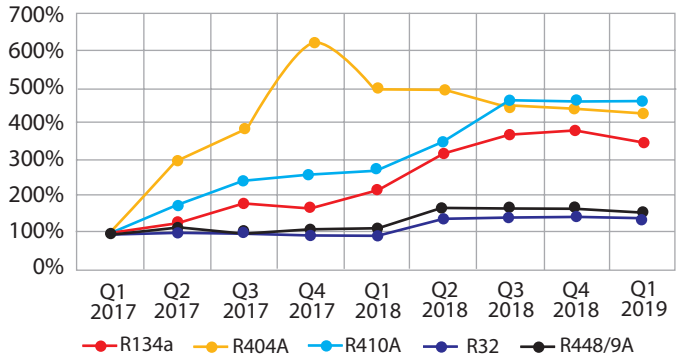


Figure 2: European Union refrigerant price increases from Quarter 1 of 2017 through Quarter 1 of 2019.

As a practical example of how innovation accelerates the transition, it's worth examining the case of a military supermarket in a hot-climate region. In 2018, the United Nations Industrial Development Organization (UNIDO) supported the successful implementation of a CO_2 refrigeration system in the store.

The region experiences 90F and higher ambient temperatures in the summer. Compared to using HFCs at those temperatures, employing CO_2 refrigerant within its normally high operating pressures was not energy efficient.

Nevertheless, several advanced technologies were employed to go beyond CO_2's traditional ambient temperature limitations. The bottom line: The CO_2 system supplying display cabinets has an extremely low GWP of 1.0 and provides up to 30 percent energy savings compared to the incumbent solutions based on R-22 and R-404A refrigerants. A technology hub has been established to explore adopting the transcritical CO_2 solution for air conditioning in the store.

Adding to the momentum are philanthropic-funded initiatives, such as the Kigali Cooling Efficiency Program (KCEP) promoting low-GWP solutions in developing countries. Other non-governmental organizations (NGOs) and academic institutions are also stepping up to help raise the level of innovation to define the HFC-free cooling technologies of the future.

Speed Bumps in Accelerating Toward Low-GWP Refrigerants

Several HFO refrigerant formulations have been readily adopted for a number of applications. Automotive manufacturers for car air conditioners use R1234yf. R1234ze(E) is used in innovative centrifugal compressors employing magnetic bearings.

Some low-GWP refrigerants are flammable. Some are toxic. Some are both. American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 34 and International Standards Organization (ISO) 817 standards have been developed to classify flammability and toxicity.

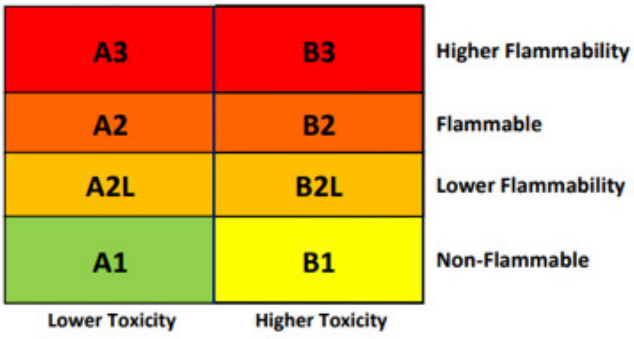
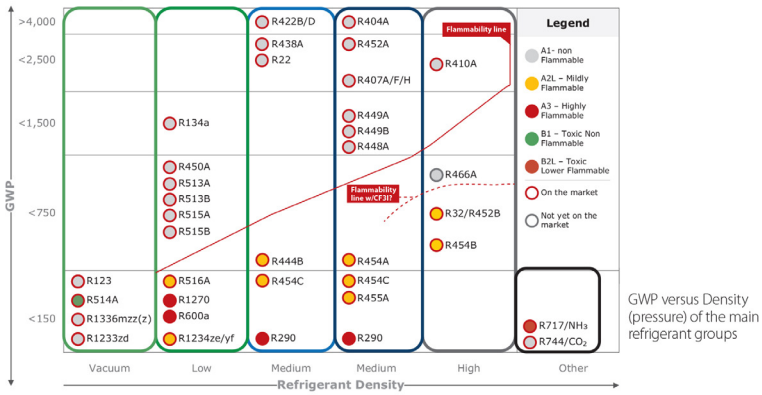


Figure 3: ISO 817 refrigerant classification scheme.

Lower GWP properties tend to correlate with higher flammability/toxicity characteristics. For example, HFC refrigerant R-410A (with a 2088 GWP) is non-toxic, non-flammable and classified A1. The HFO refrigerant R1234yf (with a 4 GWP) is non-toxic, mildly flammable and classified A2L. Hydrocarbon refrigerants (R-600a isobutane and R-290 propane) are highly flammable (A3). Ammonia (R-717) has higher toxicity and flammability (B2). CO_2 (R-744) is an exception with no flammability or toxicity (A1).

The correlation between GWPs, refrigerant density (weight per volume) and safety classifications of various refrigerants is of great concern to HVACR system manufacturers and specifiers.



GWP versus Density (pressure) of the main refrigerant groups

Figure 4: Main refrigerants at play—A complex picture in continuous evolution. (Source: "Refrigerant options now and in the future: A white paper on the global trends within refrigerants in air condition and refrigeration seen from a Danfoss perspective," August 2018. https://www.danfoss.com/media/7174/low-gwp-whitepaper.pdf).

Blends of HFOs and HFCs are being developed to optimize performance and safety. Whether using HFOs, natural refrigerants or blends, HVACR manufacturers must innovate technologies that maximize efficiency and minimize risk for the selected refrigerant.

Developments of new technologies make it easier for manufacturers to balance safety and environmental responsibility. Some leading retailers have been using R-290 (propane) in equipment for over a decade. Taking advantage of R-290's excellent thermodynamic properties — such as volumetric capacity, capacity and coefficient of performance (COP) — systems are operating successfully with a charge limited to 150 grams (5 ounces) for safety.

Further research and product development led the International Electrotechnical Commission (IEC) to propose a 500-gram (1.1-pound) limit for R-290 in single commercial refrigeration appliances. The new IEC 60335-2-89 standard was passed in May 2019.

As time passes, it's logical to think that Europe and the U.S. will continue to explore the balance between safety, efficiency and the environment — but not at the expense of endangering users and technicians.

New design and safety measures are needed to avoid flammability in occupied spaces and during servicing. For over a century in the U.S., HVACR manufacturers and service technicians have been working with A1 refrigerants.

The service industry, in particular, will need to become more familiar with flammable refrigerants. Safety is a vital factor relative in a refrigerant sustainability triangle that includes environmental and economic factors.

Other factors come into play depending on the properties of the refrigerant. With some HFO refrigerants, for example, flammability can present a safety issue, as previously discussed. Cost can also be a factor, as HFO formulations are more expensive to produce, and supplies are constrained. Finally, environmental concerns can still be an issue in several countries, because some HFOs break down in the lower atmosphere, forming fluorinated products.

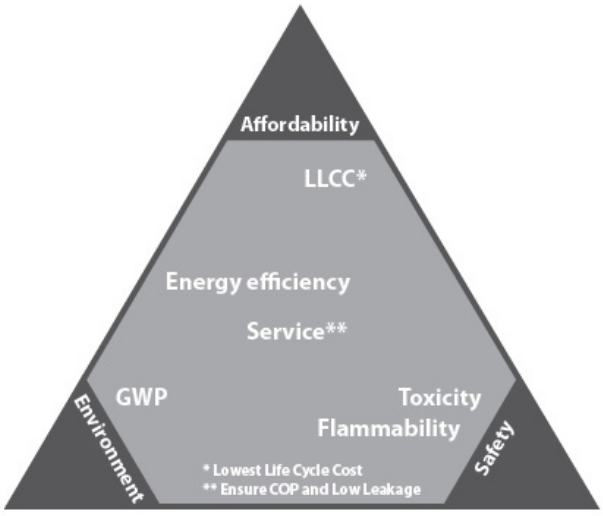


Figure 5: Refrigerant Sustainability Triangle: Safety considerations involve the planet and people. Training and certification programs of service technicians are essential to reducing risks. Economic factors primarily include first costs for equipment and installation. Optimized system design and rebates/incentives/tax credits can speed up the return on investment (ROI). Environmental considerations involve a mix of refrigerant GWP, energy efficiency in real-world operation and integration with demand response, thermal storage and using power supplied by a decarbonized grid.

Conclusion

Recent technological developments are supporting the transition to low-GWP refrigerants. While policies may fluctuate, research and innovation are bringing proven products and platforms to market that can be implemented today in more food and commercial refrigeration applications than ever before.

Visit refrigerants.danfoss.com to learn more.

Product Description

All over the world, refrigerant legislation tightens as the consequences of climate change becoming increasingly clear, making transiting to climate-friendly refrigerants, like CO_2, a top priority. With thousands of CO_2 refrigeration installations worldwide, Danfoss has a proven record of helping customers make the refrigerant transition while saving energy, maintaining system reliability, and ensuring food safety.

CO_2 Adaptive Liquid Management (CALM) pushes the already impressive savings inherent to CO_2 refrigeration even further. Combining Danfoss' Liquid Ejector, which uses expansion energy from the gas cooler to remove liquid from the suction side, and the Adaptive Liquid Control (ALC) case controller algorithm, which safely injects more refrigerant into the evaporator, CALM is able to increase the evaporation temperature and raise the controller superheat to nearly zero.

By fully utilizing an evaporator's surface, CALM optimizes evaporator performance, increases suction pressure, and improves energy efficiency by as much as 10%, without the need for any additional equipment. CALM is available for all climate zones and store sizes, making CO_2 refrigeration available to food retailers all over the world.

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Case Study: Weis Markets

Engineering Tomorrow Allows Environmentally Focused Retailer to **Achieve Goals**

Danfoss Helps Weis Markets Reduce Refrigerant Charge, Energy Consumption and Overall Carbon Footprint

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Founded in 1912, **Weis Markets** began as a neighborhood grocer in Sunbury, Pennsylvania — a small town nestled against the Susquehanna River. Today, the company owns more than 200 stores throughout the Mid-Atlantic, from New York to Virginia, and employs more than 19,000 people in its stores, distribution centers, corporate office, and manufacturing facilities.

Still run by the Weis family, Weis Markets has today, and throughout its history, rooted itself in steadfast dedication to local farmers, giving back to its communities, and minimizing its environmental footprint.

Weis reduced its refrigerant charge by 65 percent, lowered operating condenser design temperatures — and, thus, compressor design conditions as well, cutting energy costs even further.

In fact, the supermarket chain has set ambitious goals of reducing its carbon footprint by 20 percent by 2020—an objective that it has already surpassed; since 2008, Weis has reduced its carbon footprint by more than 20 percent. It also aims to reduce its recycling rate by five percent each year, with an end goal of zero waste.

A member of the US Environmental Protection Agency's GreenChill program with 15 GreenChill-certified stores, Weis is striving to reduce its energy use by two percent annually and has saved more than $2 million by deploying efficient and environmentally-friendly equipment throughout its stores to reduce costly and harmful refrigerant leaks.

Evolving System Design to Meet Goals

What Weis Markets has accomplished in terms of sustainability and efficiency can in part be attributed to a forward-thinking and open-minded team — and a willingness to evolve its refrigeration design strategy.

Ten years ago, Weis employed a refrigeration design that featured two low-temperature and two medium-temperature central distribution racks per store, eventually transitioning from R-502, a chlorofluorocarbon (CFC), to R-404A, a hydrofluorocarbon (HFC) blend with lower ozone depletion potential.

However, increasing scrutiny of the environmental impact of refrigerants, evolving regulations, and an opportunity to further reduce costs led Weis to transition to a design utilizing one low-temperature rack, one medium-temperature rack, and a secondary glycol medium-temperature rack. This design ultimately moved Weis from R-404A (GWP 3943) to lower global warming potential (GWP) and more energy-efficient options R-407A (GWP 1923) and R-448A (GWP 1273).

By incorporating microchannel condensers, variable frequency drives, Danfoss AK-CC 550 and AK-CC 210 case controls, and Danfoss AB-QM™ pressure independent control valves on the glycol loop, Weis reduced its refrigerant charge by 65 percent, lowered operating condenser design temperatures—and, thus, compressor design conditions as well, cutting energy costs even further.

Introducing Natural CO_2 Refrigeration

But in 2018, Weis worked with Danfoss to take the next step toward dramatically slashing the global warming potential of its refrigeration systems; its first transcritical CO_2 refrigeration system went live in July 2018.

Supermarket systems can leak up to 20 percent of their refrigerant, but by replacing HFCs with CO_2 reduces refrigeration cost, accelerates positive environmental impact, and serves as a future-proof solution in a period of evolving regulations and standards.

Non-toxic and non-flammable CO_2, which offers zero ozone depletion potential and GWP as low as one, can deliver very high performance in some commercial refrigeration systems through improved heat transfer and low condensing pressures. It also has high volumetric efficiency, low power consumption, and refrigerant charge reduction.

"We initially discussed partnering with Weis to do a CO_2 store a few years ago," says Stephen Renz, account manager at Danfoss. "They've been a tremendous proponent of environmentally-friendly refrigeration design in their stores, so once their team was comfortable with design for the new transcritical CO_2 store in Randolph, New Jersey, we were thrilled to help them bring it to life."

In fact, the Randolph store was designed with multiple sustainability measures in mind. In addition to environmentally-friendly CO_2 refrigeration, the 54,000-square-foot store features LED lighting; low-flow devices that support water conservation efforts; and energy control through demand response programs to reduce power usage during peak days and to reduce the store's load on the power grid. The store also uses enclosed refrigeration cases to reduce energy use, and advanced refrigeration technologies — like those supplied by Danfoss, to reduce refrigerant use by 60 percent compared to conventional systems.

The store's refrigeration cases utilize Danfoss AK-CC 550A and AK-SC 210 case controls that allow food retailers like Weis to ensure proper and constant temperature control of its refrigeration cases and rooms to ensure optimum performance, low energy consumption, and food safety. The controllers also feature an Adaptive Defrost functionality that allows the case controller to skip scheduled electric defrost cycles that are not necessary, based on real-time monitoring of the evaporator performance.

"Because of our extensive experience with CO_2 systems around the world, our team also worked closely with the Weis team, as well as the system manufacturer and refrigeration contractor, to commission and optimize the store," Renz says. "And it was one of the smoothest startups Weis has ever had, giving them extra confidence in the ability to hopefully deploy the transcritical CO_2 refrigeration system design throughout more stores in the future."

In just two weeks of operation during the end of August — when temperatures can soar in New Jersey, kilowatt-hour usage in the store was nearly 40 percent less than one of the retailer's older stores using a five-compressor-rack design, and, still, more than 25 percent less than a newer store incorporating a secondary glycol loop.

"Some of our goals at Weis Markets are to reduce our refrigerant charge, energy consumption, equipment costs, and the amount of GWP refrigerants being used—all to lower our corporate climate impact," says Paul Burd, manager, refrigeration engineering at Weis Markets. "Danfoss has been instrumental to the installation, startup, and commissioning of our first CO_2 store. They provided a team onsite to train our personnel, coordinate project construction, program controls, and verify operation throughout the project. Danfoss is a valuable partner for us."

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