



Towards energy-efficient refrigeration with **natural refrigerants**

UNDERSTANDING THE BENEFITS OF HYDROCARBONS

Impact of cooling

The impact of cooling technologies such as refrigeration and air conditioning on the environment is twofold:

- **Indirect emissions** (energy-related) of these installations that contribute to CO₂ emissions and reduce global energy resources.
- **Direct emissions** (refrigerant-related) due to leakage of certain refrigerants during manufacturing, maintenance, regular use, improper disposal and reclamation of refrigeration & AC equipment.

Globally, the direct emissions are estimated to grow from 7% of total CO₂ emissions today to 13% by 2030. Reduction in refrigerant emissions needs to go hand in hand with reducing energy-related emissions by adopting technologies that are energy-efficient.

Supermarkets are among the most energy-consuming commercial buildings. In food retail stores, refrigeration systems account for 30-60% of the total energy use making them the highest electricity consuming system in the store.¹ Given the long lifetime of cooling systems, the choices made today will impact the store's energy consumption for many years.

¹ Minetto S., Marinetti S., Saglia P., Masson N., Rossetti A. (2017). Non-technological barriers to the diffusion of energy-efficient HVAC&R solutions in the food retail sector. International Journal of Refrigeration 86 (2018) 422-434.

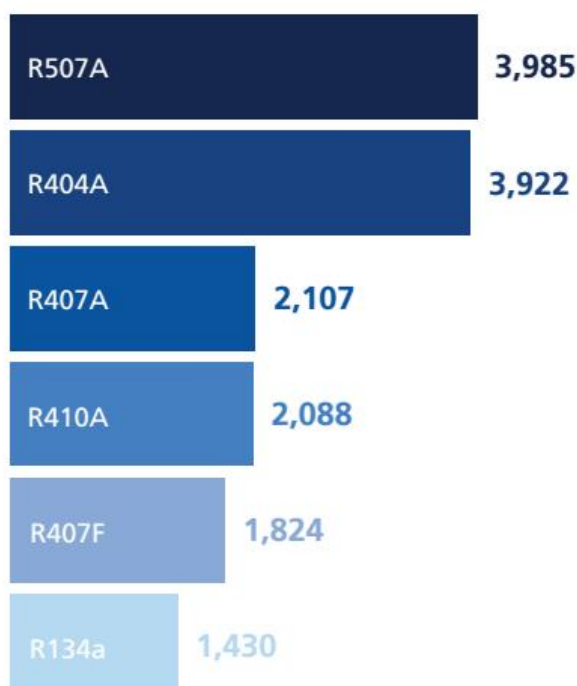
Why target hydrofluorocarbons?

Fluorinated greenhouse gases (f-gases) are man-made gases that do not damage the ozone layer, but are powerful greenhouse gases; up to 15,000 times more powerful than CO₂ (based on a global warming potential (GWP) measured over 100 years). The most common f-gases are hydrofluorocarbons (HFCs), often used as refrigerants in air conditioning, refrigeration and heating equipment.

With the phase-out of ozone-depleting substances (ODS) such as chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) under the Montreal Protocol on Substances that Deplete the Ozone Layer, the use of HFCs as main replacements has been increasing. HFCs have become the fastest-growing source of greenhouse gas emissions globally.

GWP of common HFC refrigerants

GWP (100 years)



International action to cut HFC emissions

Legislators across the world are taking action to reduce the emissions of HFCs, which will only intensify with the implementation of the Kigali Amendment to the Montreal Protocol.

The Paris Agreement reached among nearly 200 countries aims to keep the global temperature rise below 2°C, while pursuing efforts to limit it to 1.5°C (compared to pre-industrial levels).

In October 2016, the world's nations adopted the Kigali Amendment to the Montreal Protocol, a historic accord committing economies worldwide to significantly reduce consumption and production of HFCs. The reduction of HFCs globally has been identified as one of the most important actions that can contribute to avoiding 0.5°C warming by 2100.

The European F-Gas Regulation is recognised as the most ambitious legislation to regulating HFCs to date. While aiming to limit the consumption of HFCs by 79% by 2030 (in CO₂ equivalent) in the EU countries it also has a global impact, as a large number of companies using and manufacturing HVAC&R equipment operate internationally. The EU legislation also serves as an inspiration to other governments looking to introduce legal measures to cut HFC emissions.

HFC-free alternatives

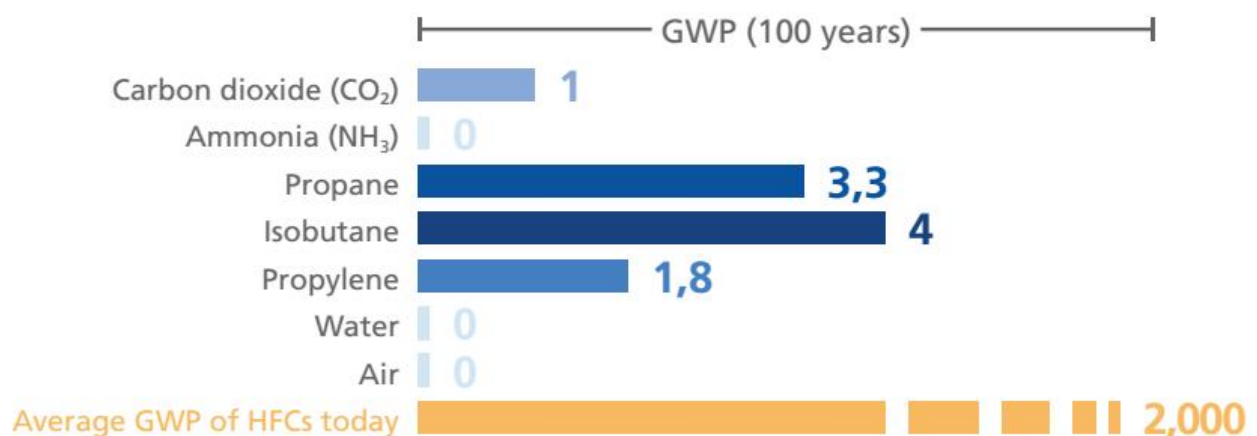
Existing lower GWP refrigerants include natural refrigerants - hydrocarbons, such as propane (R290) and isobutane (R600a), carbon dioxide (R744), ammonia (R717), air and water.

Natural refrigerants are often considered as a future-proof solution, with

well-identified thermodynamics and properties as they were used as refrigerants prior to the 1950s - before fluorocarbon refrigerants became commonplace.

The precision of the term 'natural refrigerants' is sometimes debated, given that, to be used as refrigerants, ammonia, carbon dioxide, and hydrocarbons also undergo an industrial purification and manufacturing process. However, there is today a well-established distinction between substances whose chemical properties and safety aspects have been studied in their entirety and those fluorinated gases. Given their chemical complexity and comparatively short period of usage, fluorinated gases have confirmed and/or unknown negative effects on ozone depletion, global warming and ecological safety, and therefore, are subject to continued debate.

GWP of natural refrigerants



Benefits of hydrocarbon-based refrigeration

Main advantages of hydrocarbon refrigerants



Zero ODP

(ozone depleting potential)



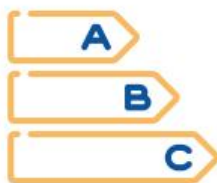
Safe

when handled properly
in accordance with
industry-agreed standards



Very low GWP

(global warming
potential) < 4



Energy-efficient

thanks to excellent
thermodynamic properties



Future-proof

In line with current and
future legislation



Cost-effective

low refrigerant price,
lower running costs



Non-toxic

Energy-efficient HFC-free technologies such as those using hydrocarbons offer several benefits to retailers, consumer brands and other users of cooling equipment, including:

A. Regulatory compliance

Natural refrigerants, such as hydrocarbons, are not subject to any legislative and/or regulatory requirements under the global HFC phase-down, including the Kigali Amendment to the Montreal Protocol and the EU F-Gas Regulation. The restrictions on fluorinated refrigerants have become stricter across the world.

Moreover, prices of natural refrigerants are not subject to inflation due to financial mechanisms such as HFC taxes in some countries or phase-down quotas. The use of natural refrigerants will become more attractive as HFC prices rise.

"For us, natural refrigerants are the default option. There is nothing else. If you build any other type of store now, you're building a liability." Alex Kuzma, Woolworths

"The impact of HFCs on the environment today is significant. They make a major contribution to the greenhouse effect, and that's why climate science requires them to be phased down. We want to stay one step ahead of that curve, while at the same time reducing our impact on the environment." Yassine Rami, Lidl France

B. Low impact on the environment

Hydrocarbons are non-toxic refrigerants that have no ozone depleting (ODP) and minimal global warming potential (GWP).

"We adopted hydrocarbons for two reasons – one, because they help to deliver the energy efficiency that we want; and two, because of their significantly lower GWP." Graeme Houghton, Heineken

C. Energy efficiency

While natural refrigerants significantly reduce direct emissions, they can also be very energy efficient, thereby simultaneously reducing indirect emissions.

R290 (propane) plug-in refrigeration units have been reported to deliver up to 30% higher energy efficiency than their HFC counterparts.² About 5-10% of this can be accredited to better thermodynamic and transport properties of hydrocarbons. The rest is most likely due to component modifications such as improved compressor or heat exchanger design, as well as variable speed drives.

"We're always on the lookout for solutions that will allow us to operate our display cabinets

and refrigeration systems more efficiently, reduce greenhouse gas emissions by using the right refrigerant and minimise our impact on the environment.

We've dedicated ourselves to operating with a focus on the future. Even if that means we have to invest more for a certain period of time. However, energy savings ultimately serve as proof of a short amortisation period and high investment security." Jens Strassburg, director – store operations management at ALDI Süd

"We see good efficiency with hydrocarbons compared to HFCs. It's a significant difference." Vincent Grass, Nestlé

Research finds propane performs better than alternatives

According to a 2017 Emerson study by the University of Birmingham³, in stores converted to hydrocarbons from remote systems using R404A, Waitrose saves 7% on electricity and 60% on gas (waste heat from the cooling loop is used for space heating). This reduces operating costs by £65,000 (€71,670) per store per year.

² Zolcer Skačanová K., Gkizelis A. (2018), Technical report on energy efficiency in HFC-free supermarket refrigeration. Available at: https://issuu.com/shecco/docs/2018_kcep_shecco_eia_technical_repo

³ University of Birmingham (2017), Retail Refrigeration: Making the transition to clean cold, Available at: <https://www.birmingham.ac.uk/Documents/college-eps/energy/Publications/Retail-Refrigeration.pdf>

D. Return on investment

Determining return on investment (ROI) on commercial refrigeration systems requires considering variables such as the cost of refrigerant, energy equipment, installation, maintenance and regulation. Understanding ROI allows a grocer to make strategic, forward-thinking decisions that not only meet today's challenges but also help future-proof the business.

In Europe - where natural refrigerants-based technology has become standard in new supermarkets, giving better perspective to analyse trends - signs of falling prices are particularly registered.

"I think [prices falling as more equipment becomes available] is a trend, and that we'll get even better prices in the future." Paolo Martini, refrigeration & HVAC manager for international support at Carrefour Group

E. Safety – when handled properly

Hydrocarbons are classified as highly flammable (A3) refrigerants, which means they need to be handled with care. Due to the flammability charge sizes are limited in certain applications. The flammable properties of hydrocarbons are well understood and managed in different applications. The safety of hydrocarbons (as well as other refrigerants) is governed by international, regional and national standards.

"R290 is a safe and reliable refrigerant when installed properly. I can't say enough good things about that. It's amazing that 150g of it can do what it does from the refrigeration standpoint." Charles Wer-nette, H-E-B

Increased charge limit for commercial refrigeration

In May 2019, the International Electrotechnical Commission (IEC) approved an increase of the charge limit of hydrocarbons in self-contained commercial display cases to 500 g from 150 g under its IEC 60335-2-89 standard.

Adopting a 500-g charge-limit standard in commercial display cases would widen the use of hydrocarbons by allowing a single circuit to be employed in larger cabinets, rather than multiple circuits using no more than 150 g of refrigerant. This major development will lead to reduced cost of equipment for the benefit of the end user.

Market trends for hydrocarbon-based refrigeration

Global use of hydrocarbons in different applications



Domestic
refrigeration
1 billion



Residential split air
conditioning
760,000



Heat pumps
220,000



Light commercial
refrigeration
(bottle coolers, ice cream
freezers, beverage
dispensers, beer coolers)
> 4.7 million



Refrigerated
cabinets
2.5 million

Domestic refrigeration

Typical applications for hydrocarbons include self-contained residential and light commercial equipment, such as domestic refrigerators and freezers, air conditioners, heat pumps and dehumidifiers as well as stand-alone light commercial refrigerators, bottle coolers, ice cream freezers, beverage dispensers and beer coolers.

Today, over 1 billion domestic fridges worldwide use hydrocarbon refrigerants (mainly isobutene, to a smaller extent propane). Overall, hydrocarbons are now covering about 65 – 70% of the use in domestic refrigeration, which is expected to grow to 75% by 2020.

Commercial refrigeration

The most common natural refrigerant chosen to replace high-GWP HFCs in plug-in commercial refrigeration systems is propane (R290). Four major consumer brands (The Coca-Cola Company, PepsiCo, Red Bull and Unilever) have placed more than 4.7 million hydrocarbon-based light commercial units (bottle coolers, ice

cream freezers, beverage dispensers and beer coolers) on the market globally.⁴

According to the data collected from leading manufacturers of hydrocarbon-based units, there are approximately 2.5 million plug-in refrigerated showcases / cabinets used in supermarkets globally.⁵

According to system manufacturers surveyed by sheccoBase, strong growth in the range of 10-20% is expected in the next 1-2 years for HC-290 plug-in systems in Europe, mainly driven by high customer demand and future proofing against legislation on high-GWP refrigerants.

According to most manufacturers higher energy efficiency is guaranteed from R290 plug-ins compared to HFC counterparts. Most stated energy efficiency gains are between 20-30%, whereas a few indicated their R290 systems can be up to 40% more energy-efficient than HFC plug-ins.

The main disadvantage of plug-in systems is that the condenser heat is released directly to the sales area, creating an additional heat load to the supermarket and increasing the energy costs (AC requirement). To tackle the heat disadvantage, innovative waterloop solutions have been developed and rolled onto the market using hydrocarbons, mainly propane and propylene. The waterloop systems are designed so that every cabinet has its own self-contained refrigeration unit. The heat generated is not released to the surrounding environment of the store, as it is carried outside by a waterloop to a simple dry cooler.

Hydrocarbon plug-in systems combined with water-loop technology are gaining presence in the global market. sheccoBase, the market development arm of shecco, estimates there are more than 1,900 stores globally using the hydrocarbon water-loop technology.

Heat pumps and air conditioning

Besides refrigeration, hydrocarbons are also a suitable alternative of air conditioning and heat pump applications. With the support of international organisations China converted 18 room AC production lines to R290 with a production capacity of 4,500,000 units per year, as well as three room AC compressor production lines with a production capacity of 5,400,000 units per year. By August 2019, up to 160,000 hydrocarbon-based residential AC units have been produced in China. Besides this, Indian manufacturer Godrej has introduced more than 600,000 units in its market. With the update of international and local standards the potential of hydrocarbon-based AC could be significant.

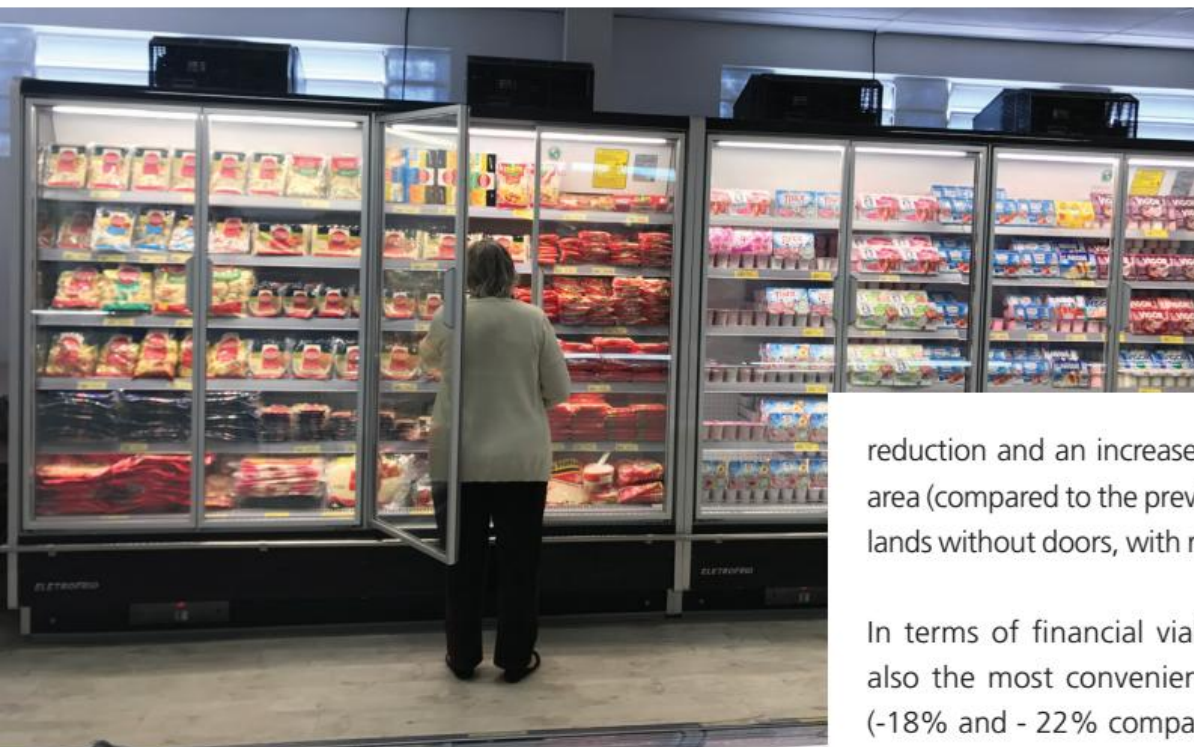
Based on the data collected from heat pump manufacturers the estimated number of heat pumps with hydrocarbons today in Europe is around 220,000 units. With more than 25 companies offering such products already, the rate of adoption is expected to grow.

⁴ Interview with Refrigerants, Naturally!

⁵ LIFE FRONT (2018), Impact of standards on hydrocarbon refrigerants in Europe, Available at: <http://lifefront.eu/wp-content/uploads/2018/10/impact-of-standards-on-hydrocarbon-refrigerants-in-europe-life-front-report-1.pdf>

Case studies

CASE STUDY 1: R290-COOLED SUPERMARKET IN BRAZIL



Retailer: Mig Supermercados

Key parameters:

Store size: 1,600 m²

Mig Supermercados switched from a remote R22 system to R290-based solution with hermetic reciprocating compressors.

System information:

For its 1,600-m² store, Mig Supermercados (a supermarket chain in Southern Brazil) decided to retrofit its refrigerated area with environmentally friendly cabinets using R290.

Compared to the previously semi-hermetic system using R22 and an alternative using CO₂, the R290-based solution resulted in improving aesthetics of the store (attracting new clients), leading to approximately 97% of CO₂ emission

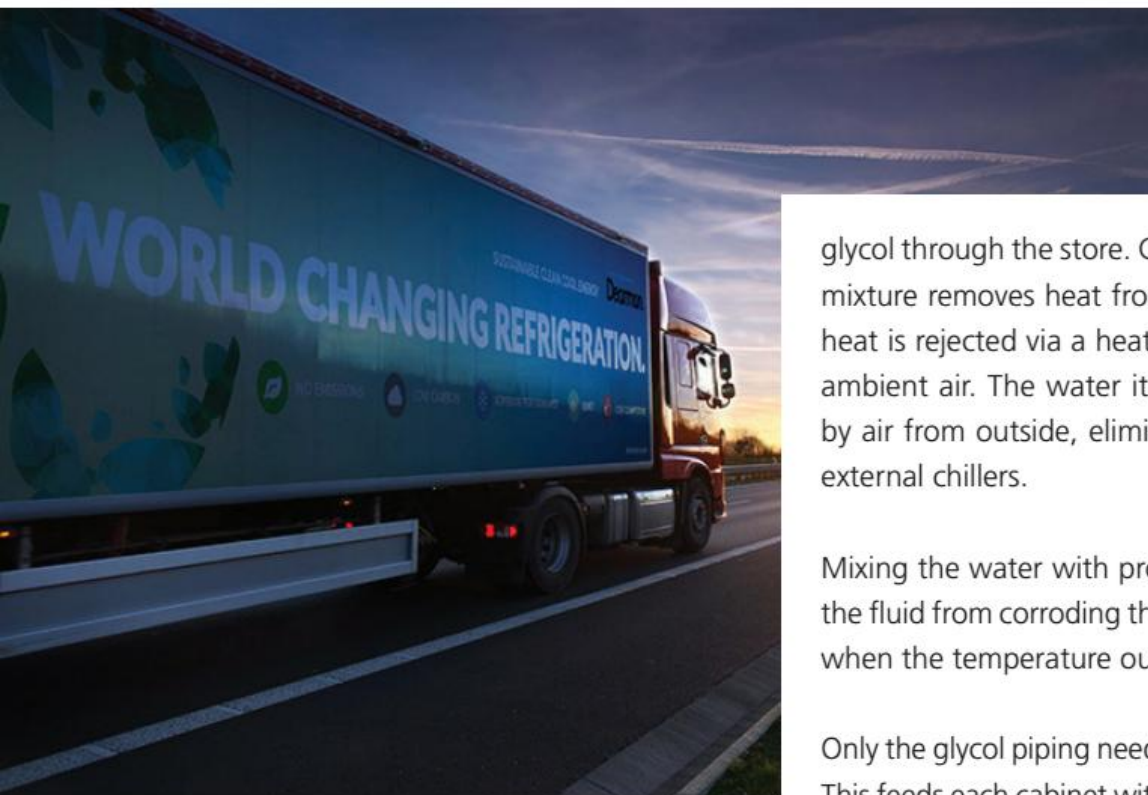
reduction and an increase in the merchandise area (compared to the previous reach-ins and islands without doors, with remote refrigeration).

In terms of financial viability this system is also the most convenient one of the three (-18% and -22% compared to the R22- and CO₂-based systems respectively), given its low maintenance and energy consumption costs (with a possible saving of €1500/month and 35% reduction of total cost of ownership). Considering only the refrigeration system, the R290-based solution indeed consumes almost half (270 vs 425 kWh/day) the amount of the one using R22. The use of doors in the R290-based hermetic reciprocating technology (and absent in the R22 system) facilitates some of the energy savings.

Current results:

Switching from a remote R22 system to R290-based solution with hermetic reciprocating compressors delivered a 35% reduction in the total cost of ownership by reducing energy consumption by 37% and offering up to €200,000 in maintenance cost savings over a period of one year.

CASE STUDY 2: HYDROCARBON WATERLOOP SYSTEM IN BELGIAN CARREFOUR STORE



Retailer: Carrefour

Key parameters:

Store size: 200 m²

In September 2016, Carrefour Belgium opened its first store using waterloop refrigeration system with propylene (R1270).

System information:

Each of the store's eight cabinets was fitted with one or two self-contained, factory-sealed, and pre-charged refrigeration systems featuring a compressor, an evaporator and a water-plate condenser.

A hydraulic circuit connecting the cabinets, fitted with pumps and an external dry cooler, circulates a mixture of water and propylene

glycol through the store. Circulating the water mixture removes heat from the cabinets. The heat is rejected via a heat exchanger into the ambient air. The water itself is cooled down by air from outside, eliminating the need for external chillers.

Mixing the water with propylene glycol stops the fluid from corroding the pipes and freezing when the temperature outside is cold.

Only the glycol piping needed installing on site. This feeds each cabinet with the necessary condensing glycol. The glycol is cooled down by a dry cooler outside. This eliminates the need for hydrocarbon-based chillers located outside the store.

Fitting such a system also saves space by eliminating the need for a refrigeration rack. The compressors are integrated into the top of each cabinet. The cabinets themselves are fitted with double doors and LED lighting to save energy.

Total refrigerant charge in the whole system is less than 5.5kg, divided between different circuits in each cabinet

Current results:

According to Carrefour's preliminary calculations and modelling these types of systems have increased energy efficiency and are a solid solution for a medium-sized stores.

CASE STUDY 3: FROZEN FOODS RETAILER OPTS FOR R290 CASES



Retailers: Wild Fork Foods

Key parameters:

Wild Fork Foods, a new retail outlet that offers only frozen foods, opened three roughly 460m² stores in South Florida in December 2018, and equipped them each with 40-50 air-cooled propane (R290) frozen-food cases.

System information:

The cases include both horizontal chest units throughout the store and vertical reach-ins that are built into the perimeter wall, overhanging the retail space.

Wild Fork thus became one of a small number of food retailers operating its entire sales floor with self-contained R290 cases.

The single-circuit Wild Fork cases all have doors or lids, and defrost themselves. The advantage of using air-cooled display cases is that allows for high flexibility and possibility to add refrigeration capacity to an existing store without any disruption in store operation.

Current results:

Wild Fork installed the R290 cases to be "more environmental" and because "it was conducive to what we wanted to do," said Layli Sobhani, head of brand and marketing for the retailer. In particular, the cases "give us the flexibility to build out the stores consistently to fit all of our products."

In addition, she expects the cases to save the stores energy because they all use doors.

sheccoBase

sheccoBase is the market development arm of shecco - a global market accelerator helping its partners in the heating, air conditioning and refrigeration sectors bring their innovative solutions faster to the market. We specialise in integrated services and products to advance the use of the five natural refrigerants carbon dioxide (CO₂), ammonia (NH₃), hydrocarbons (HC), water and air. Our portfolio comprises activities in three areas: media, events and market development.

Email us at

europe@shecco.com

Talk to us on the phone

+32 (0)2 230 3700

Our mailing address

shecco Europe Rue Royale 15,
1000 Brussels,
Belgium