Low-GWP Alternatives in Commercial Refrigeration: Propane, CO₂ and HFO Case Studies
CASE STUDY
CarrefourSA Express Kurtköy Commercial Refrigeration

Name of the Store/facility: CarrefourSA Express Kurtköy

Location: Kurtköy, Turkey

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Type of Facility: Hypermarket, Store Area = 765 m$^2$, Food & Department Store.

Technology Transition: Transition from High-GWP refrigerant R-404A to CO$_2$.

Project Background: As part of the Carrefour Group’s effort to mitigate climate change by reducing HFC refrigerant charge and refrigerant leakage, the Group has set a goal to phase out HCFCs in new refrigeration equipment by 2015. Currently, Carrefour is progressively rolling out full CO$_2$ systems, having installed its first CO$_2$ transcritical refrigeration system in Istanbul, Turkey, at the Kurtköy-Millennium Carrefour Express. Fig. 1 shows photo of the store in Kurtköy, which has a sales area of 765 m$^2$. The retrofitted refrigeration system in the Turkish Kurtköy store entered into operation on 9 May 2012, and is one of four sites operated by the retailer that use 100% natural refrigerants. In more than 30 stores across Europe, Carrefour was already using a hybrid solution such as a cascade system, which combines synthetic refrigerants and CO$_2$, but the change-over to an installation that operates solely with CO$_2$ marked a clear shift to natural refrigerants. Carrefour plans to continue to set up new stores across Europe using natural refrigerants.

"Carrefour states that the market penetration of CO$_2$ commercial refrigeration could be further accelerated if qualified contractors were more widely available to cater for the needs of the booming CO$_2$ refrigeration market. This is relevant for countries outside the European market and more particularly in Asia and Latin America." — Jean-Michel Fleury, Director of Assets Carrefour Group.

New System/Installation: Food refrigeration accounts for two-thirds of the Carrefour Group’s greenhouse gas emissions. The emissions arise from refrigerant leaks, as well as from electricity consumed by refrigeration equipment. To reduce these emissions, Carrefour Turkey is piloting a highly innovative solution - using the natural fluid CO$_2$ for both refrigerators and freezers at the Kurtköy store. The technology used in Turkey is new to that part of the world, and is only the fourth time it has been used by the Carrefour Group. CO$_2$ is being used as the alternative to the original HFC refrigerant R-404A. R-404A, with a GWP of 3,922, is an HFC refrigerant, a colorless, odourless mixture which is used as a replacement for R-22, a refrigerant which is being phased out under the Montreal Protocol.

The new Kurtköy’s CO$_2$ installation has the following dimensions:

There are 13 showcases for positive temperature products, and two for negative temperature products, which equates to 33 meters of refrigeration displays. Compressor racks are used to provide cooling for these showcases at negative and positive temperatures. The capacity of the positive rack compressors is 40 kW, and negative rack compressors 4 kW.

The technical specifications for the compressor racks include:

The compressor rack for medium temperature applications is composed of four Bitzer compressors with a total refrigeration capacity of 67.44 kW, and a coefficient of performance (COP) of 1.12. This COP
is during the summer when the gas cooler outlet temperature is 45°C, while in winter time the COP is 6.99. The compressor rack for the low temperature side is composed of one Bitzer compressor with a total refrigeration capacity of 4.80 kW, with a COP of 4.58. Fig. 2 shows a photo of the five-compressor rack.

The design using CO₂ is similar to a typical transcritical system. Since the pressure level is higher than 70 bar the piping design requires the use of steel pipes throughout. A transcritical CO₂ system operates in transcritical mode whenever the refrigerant is above 31°C. The condenser becomes a gas cooler at temperatures above 31°C and the CO₂ leaving the evaporator is supercritical, a state where vapour cannot condense and one cannot distinguish liquid from vapour.

Where the pressure level is less than 45 bar, the design is like that for any traditional refrigerant.

The system also has a solution for decreasing the ambient temperature by using the ChillBooster™ adiabatic air cooling system. The ChillBooster™ is manufactured by CREA (Italy).

Fig. 3 is a schematic for the ChillBooster™ system used for high ambient conditions. The system works on cooling the air to a lower temperature going over the coils by evaporative cooling. ChillBooster™ atomises water into very fine droplets that evaporate spontaneously, cooling the air. The coil is thus cooled by a flow of colder air and droplets of water, allowing more favourable operating conditions and thus increasing the cooling capacity of the system.

ChillBooster™ can be used as an extra cooling step only on high temperature days. The droplets of water are evaporated by absorbing heat from the air and, as a consequence, it can decrease the air inlet temperature by up to 15°C to help the system run in optimal conditions (see Fig. 3). This system works best in dry climates, but it is still possible to give reasonable results in higher humidity areas. The system works everywhere except in areas that have both a high temperature and high moisture content simultaneously.

![Fig. 2 The CO₂ compressor rack](image1)

![Schematic of the ChillBooster™ System](image2)

![Fig. 3 Schematic for the ChillBooster™ showing how the high ambient temperature air is cooled by water droplets before passing over the coil.](image3)
Performance:
The system has been operating in Kurtköy, Turkey where the annual average temperature varies from 0.5° C to 25.7° C. In only 12 months of operation, the technology has significantly reduced the environmental impact of the store. The CO₂ used in the refrigeration system is around 3,922 times less potent in terms of global warming potential than the refrigerant (R-404A) previously used at Kurtköy.

The quantity of CO₂ needed for the refrigeration units is approximately one-third less than the refrigerant charge required by a conventional system.

The performance of the CO₂ system is compared to similar cooling capacity systems operated in roughly similar climatic conditions using R-404A.

The quality of the pipe fittings has been improved and as a result, refrigerant leaks are expected to be reduced by 75%.

The CO₂ solution improves the energy efficiency of the refrigeration units by around 15%, which equally limits CO₂ emissions resulting from electricity consumption.

Advantages of this CO₂ System

- High-GWP refrigerants (which can be a direct contributor to global warming when leaked to the atmosphere) are reduced.
- Total elimination of HFCs from the system.
- High Volumetric capacity - The system can absorb much more heat than an HFC-based system, resulting in reduced compressor and pipe size for the same cooling effect.
- Low HFC refrigerant charge for subcritical systems
- Lower than HFC Refrigerant Costs - CO₂ costs are currently 90% less expensive than traditional refrigerants (US$2.2/kg versus US$24.2/kg for R-404A).
- Reduced Carbon Footprint - CO₂ has a GWP of 1 vs. HFC which has a GWP of 3,922 for R-404A.
- Reduced Carbon Emissions - Because the refrigerant is confined to a machine room, there are fewer braze joints and a significant reduction in potential for leaks in the system.

Disadvantages of transcritical CO₂ System

- Higher investment cost (the components capable of being operated safely in such high pressure applications can be more expensive).
- The COP of the system is reduced when operated in higher ambient conditions.
- CO₂ is heavier than air - importance of good ventilation in case of leakages
- Limited local expertise for service and maintenance in Istanbul. The flash gas leakage causes formation of dry ice on the system.
- Compressor range is very limited (but increasing).
- Difficult to obtain components at present.

Some of these disadvantages can be overcome with time when systems become more prevalent and through improved training of technicians.