Environmentally Sound Alternatives in

Supermarket Refrigeration

For many applications natural refrigerants are the key to construct exceptionally energy efficient equipment. In almost all cases their use leads to the lowest annual greenhouse gas emissions. During the last years well-known manufacturers have extensively developed components and designed equipment for the use of natural refrigerants. Natural refrigerants can substitute ODSs in many applications in the RAC sector. Additionally, for some time now, manufacturers and users have undertaken first tests with low-GWP HFCs as alternative refrigerants. However, due to their flammability for supermarket refrigeration these chemicals are tested in mixtures with high-GWP HFCs only and have not reached marketability yet.

Overview

In supermarkets plug-in appliances, centralised systems, and condensing unit systems can be found. However, these equipments are not solely used in this area.

In plug-in appliances with refrigerant charges of less than 150 g, the use of **hydrocarbons** (HC) is **state of the art**. Some manufacturers have equipment with far higher charges in their programme. For some areas **CO_2** is also an **interesting alternative**. Producers already developed CO_2-compressors especially for plug-in appliances.

Some halogen-free solutions are available for condensing units as well, but have yet to prove their suitability in practice.

Centralised systems using **hydrocarbons, CO_2** and **ammonia** exist in different concepts. Such systems are installed in several countries and **have become state of the art.**

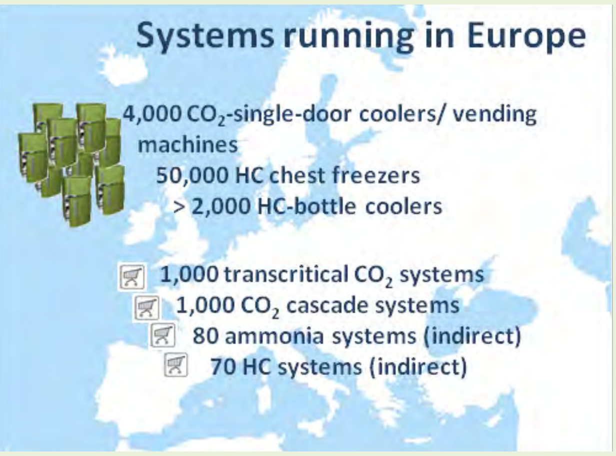

Fig. 1: Known systems running in Europe. Data: (2) (24). Pictures: (19) (26)

Fig. 2: Known systems running outside Europe. Data: (2) (3) (14) (13) (22) (5). Pictures: (25) (19)

Relevance

- Worldwide supermarket density per 1,000 inhabitants varies from 0.13 in the USA (1) (2) to more than 5 in some European countries (2).
- Worldwide numbers of **supermarkets and hypermarkets** are estimated to be **around 500,000** (3) (4).
- Worldwide about **50 million plug-in appliances** are installed (3).
- Worldwide refrigerant banks in supermarkets were estimated to be in the range of 340,000 tonnes in 2006. 15 % of this amount being CFCs, 62 % HCFCs, 23 % HFCs (5).
- Typical annual emission rates of small supermarkets in non-A5 countries are 15 to 25 %, of large supermarkets 20 to 35 % (5). For the EU experts estimate an average emission rate of 15 % (6). Typical emission rates for most of the Article 5 countries are much higher (5).

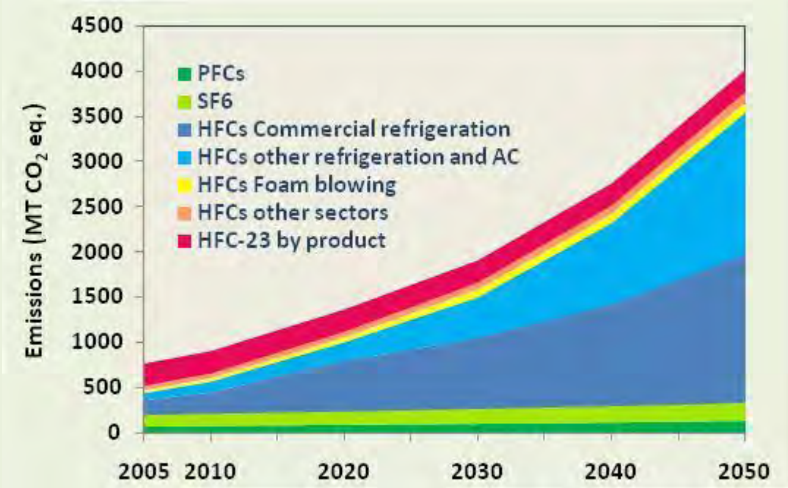

Fig. 3: Global forecasts of fluorinated greenhouse gas emissions in the main fields of application in mega tons CO_2 equivalent ("business-as-usual scenario") (7).

In global terms, fluorinated greenhouse gases currently account for about **1 - 2 % of all emissions of climate-relevant gases**. This is roughly the same as the share due to air transport. However, forecasts show that in a "business-as-usual" scenario this share will **rise to 5.9 %** (~4,000 MT CO_2 equivalents) **by 2050** (7). Other forecasts expect the share to be even larger (8).

87 % (~3,200 MT CO_2 equivalents) of F-gas emissions in 2050 will result from HFC emissions from RAC (stationary and mobile refrigeration and air-conditioning) applications, 44 % (~1,640 MT CO_2 equivalents) from commercial refrigeration (7).

In 2005 commercial refrigeration was responsible for ~50,000 tonnes of refrigerant emissions, corresponding to **~160 MT CO_2-equivalents** (7). **Centralised systems** are the biggest source of HFC emissions in the commercial refrigeration sector.

Prospects for phasing out high GWP gases

Plug-in appliances

Thousands of freezers and vending machines using hydrocarbons are installed around the world (2) (3). Manufacturers are increasingly using hydrocarbons (R 600a, R 290 and blends) or CO_2 as refrigerants (3). This is partly due to the efforts of component and appliance manufacturers to dispense entirely with the use of HFCs, but also to the users of these appliances (20) (28) (15) (21). These efforts are also fostered by the decisions in some EU countries to phase out HFCs. Today, using hydrocarbons is regarded as state of the art.

Refrigerant	GWP_{100}	Typ
R 22	1,700	HCFC
R 32	675	HFC
R 134a	1,430	HFC
R 404 A	3,922	HFC-blend
R 407 C	1,774	HFC-blend
R 507 A	3,985	HFC-blend
Opteon XP 10	~600	HFC-blend
R 1234yf	4	HFC

General

- All components of the refrigeration unit and the cooling point are integrated in the appliance.
- E. g. vending machines, freezers, bottle coolers.
- Refrigerant charge ranges from less than 150 g up to several kg (5).
- The most widely used refrigerant today is HFC-134a (23).

HC - Energy & Costs

- The energy consumption of HC chest-freezers/ice-cream freezers is 10 – 15 % lower, for HC bottle coolers as much as 30 % lower than for comparable units with HFCs (2).
- The capital cost is about the same (HC bottle coolers) or up to 15 % higher (HC freezers) (2).
- Operating costs for HC plug-in appliances are some 10-30 % lower (2).

CO_2 - Energy & Costs

- CO_2-based stand-alone equipment is available (5).
- The energy consumption of CO_2 units is lower than or equivalent to HFC appliances at ambient temperatures below 32°C (23) (3).
- Investment/component costs for CO_2-based bottle coolers and freezers are considerably higher (2).
- Operating costs for bottle coolers are approx. 10 % lower (2).

Centralised systems

In centralised systems hydrocarbons, CO_2 and ammonia are used as refrigerants in different concepts. Such systems are installed in several European countries as well as outside Europe and have become state of the art. TEWI calculations show that systems using natural refrigerants have the lowest annual emissions of greenhouse gases (2) (6).

Although they are ideal refrigerants, due to their flammability/toxicity HCs and ammonia are only used in indirect systems (public areas). Large numbers of indirect systems (all refrigerants) are used in e. g. Switzerland, Luxembourg and North America (2).

For some years now, systems have existed with CO_2 as a secondary refrigerant (low temperature, LT), as CO_2 cascade systems (LT), and as transcritical CO_2 direct expansion systems (MT+LT). The first two applications can be regarded as standard systems. In the chilled (MT) cabinet sector the use of CO_2 is technically more difficult (pressures up to 120 bar). However, all components were available by the end of 2008.

General

- Direct systems: A single (multi-compressor) refrigeration system, usually installed in a separate room, serves several refrigeration points located in the salesroom. Exceptions are distributed systems.
- The refrigerant charge varies from 800 kg to 2 t for large supermarkets (3) or less than 60 kg for small supermarkets (2).
- Indirect systems: The primary refrigerant is confined to the primary circuit, which is usually located in a separate room or outside the building. Refrigeration points in the salesroom are served by a secondary refrigerant.
- The most widely used refrigerants today are HCFC-22, HFC-404A, HFC-407C, and HFC-134a (23).

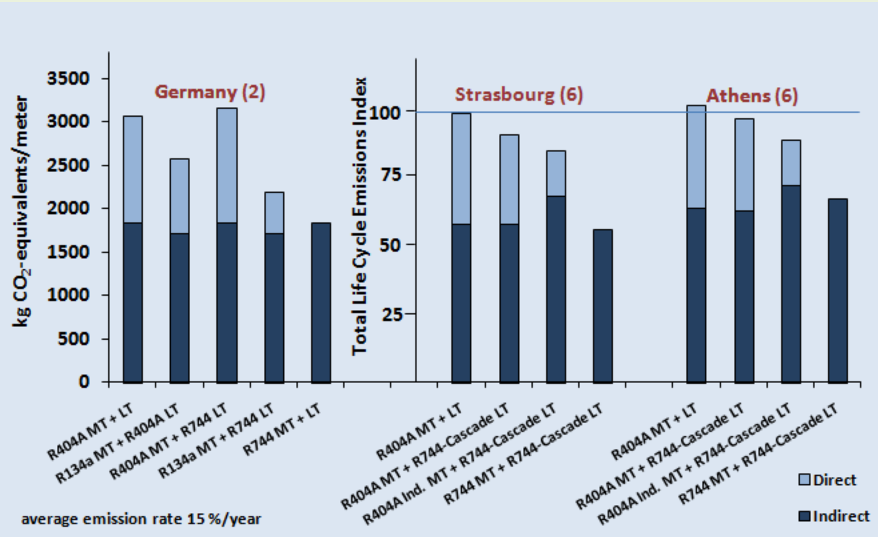

Fig. 4: Annual greenhouse gas emissions per linear meter of refrigeration unit for a German supermarket (1,500 m^2) and Total Life Cycle Emissions Indices for supermarket systems in Strasbourg and Athens. Data: (2) (6).

Energy & Costs

- Energy consumption of CO_2 direct-evaporation systems is at least equivalent to HFC standard systems up to annual average temperatures of 15°C (6)(24). For high ambient temperatures manufacturers design special systems or recommend cascade/hybrid systems.
- Energy consumption of well-designed indirect systems is in the same range as for HFC-systems.
- Often capital expenditure is still higher than for non-HFC systems. However, experts expect to see a narrowing of the costs gap soon.
- Often the use of low-GWP refrigerants allows new concepts which e. g. combine cooling and heating, and reduce costs significantly.

PLUG-IN APPLIANCES

Hydrocarbons (R 290, and R 600a)

- climate friendly
- state of the art (serial production)
- well-proven
- energy efficient
- extremely flammable → limited charge

CO_2

- climate friendly
- state of the art
- energy efficient (cold & moderate climates)
- high operating pressure
- higher costs

low-GWP HFCs (R 1234yf)

- climate friendly
- no marketability yet
- high refrigerant costs
- extremely flammable

CENTRALISED SYSTEMS

Hydrocarbons (R 290 and R 1270) or ammonia

- climate friendly
- state of the art
- energy efficiency in the range of HFC systems
- highly/slightly flammable → indirect systems
- toxic (ammonia)→ indirect systems

CO_2

- climate friendly
- state of the art
- energy efficient (cold & moderate climates or cascade/hybrid systems)
- high operating pressures (MT)
- higher costs

low-GWP HFCs (R 1234yf)

- climate friendly
- no marketability yet
- high refrigerant costs
- slightly flammable → indirect systems
- inflammable mixtures, e. g. XP 10, have a high GWP

AUSTRALIA

The Australian Government has provided a $2 million grant to the Green Cooling Council to evaluate upcoming technologies and assist supermarkets in this field (16). Around 30 commercial refrigeration and food processing facilities have installed cascade CO_2 systems so far. In 2007 the first transcritical supermarket refrigeration system was commissioned (17).

GERMANY

Since 2006 the German merchandising concern ALDI SÜD tested the technical and economical efficiency of CO_2-systems in pilot projects. End of 2009 ALDI SÜD announced to equip all new German markets with CO_2OLtec(TM)-systems (Carrier) (10).

In 2010 the German merchandising concern Lidl decided to follow a new concept for new markets. Heating and cooling is provided by a single system. Waste heat from the cabinets is the only energy source for heating. The only refrigerant used is propane (12)(11). Since 2008 the German Government gives financial support for systems using natural refrigerants.

UNITED KINGDOM

Big companies in the UK have committed themselves to phase out HFCs. In this context e. g. Waitrose is fitting all new and refitted stores with a water- and propane-based refrigeration system. The system uses 20 % less energy compared to a traditional system (18). Another example is a new 9.300 m^2 Sainsbury's supermarket where a transcritical CO_2 booster refrigeration system was installed which covers both medium and low temperature demands. The installed system is stated to achieve higher efficiencies compared to HFC-systems (9).

SOUTH-AFRICA

With support from consultant engineers local plant manufacturers in 2009 replaced two R 22-systems (1984 and 1990) by NH_3/CO_2-systems. The results were energy savings up to 30 %. The German Environment Ministry funded the projects which were carried out by GIZ Proklima (27).

Outlook

In industrialized countries the phase-out of ozone depleting refrigerants is mostly completed. Due to the lack of better solutions in many cases high GWP refrigerants like HFCs had to be used in order to be in line with the phase-out schedule under the Montreal Protocol. However, as examples show the transition from HFCs to non-halogenated refrigerants has already begun. Taking into consideration the projected emission increase of high GWP gases under Business-as-usual scenarios it is of international interest that this road will be followed further. Secondly, the important role of developing countries has to be seen in this field. There is a good chance that these countries will be able to omit high GWP refrigerants as an interim solution and directly switch to long-lasting solutions. Since these solutions are often exceptionally energy efficient there is always a benefit for the climate. Such equipment is already available. However, there is still a need for further development and support.

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