environmental investigation agency

Chilling Facts VI:

CLOSING THE DOOR ON HFCs

ABOUT EIA

The Environmental Investigation Agency (EIA) is an independent charity founded in 1984 to fight environmental crime. We have developed innovative and effective investigative methods for defending the environment and seek lasting solutions to the problems we uncover. In three decades of work, EIA has amassed an impressive series of exposés and victories, from its key role in securing the 1989 international ivory trade ban and helping bring in legislation to protect the world's precious forests to exposing the horrors of China's tiger farms and pushing whale meat off the menu in Japan.

We also play a unique and essential role in combating climate change. At European level, we successfully campaigned for stricter curbs on fluorinated gases in the new F-Gas Regulation adopted in March 2014, a deal which will see the supply of hydrofluorocarbons (HFCs) in the European Union (EU) dramatically cut over the next 15 years. At the international level, EIA continues to be the most active NGO calling for a global HFC phase-out.

ACKNOWLEDGEMENTS

Report design by:
www.designsolutions.me.uk

October 2014

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WHAT ARE HFCs?

Primarily resulting from the phase-out of ozone-destroying chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs) are the world's fastest growing source of man-made emissions, rising at an alarming rate of 10-15 per cent a year.[1]

They are powerful greenhouse gases (GHGs), with global warming potentials (GWP) hundreds or thousands of times more powerful than carbon dioxide (CO2). Left to grow, they will account for 20 per cent of total GHG emissions by 2050.[2] Phasing out these gases in favour of climate-friendly alternatives represents one of the most viable and cost-effective solutions to tackling global climate change in the short term.

THE REPORT

Since 2009, EIA's annual *Chilling Facts* report has documented the growing uptake of natural refrigerants among some of the world's leading retailers, reflecting a market shift towards climate-friendly refrigeration in the supermarket sector.

In the past two years alone, we have seen the number of stores in Europe using natural refrigerants grow from 730 to 1889 among our surveyed retailers. A key development this year has been the adoption of the new EU F-Gas Regulation which will restrict HFC use by reducing the availability of these chemicals by 79 per cent by 2030. With shrinking supply and a number of bans on the use of HFC-based equipment set to enter into force within the next decade, it is crucial that retailers move now to stay ahead of the curve.

Technological advances and improvements in system design will help accelerate the transition. Notably, the use of parallel compression technology in transcritical CO_2 refrigeration systems in southern Europe has helped pave the way for the emergence of cost-competitive natural refrigerant systems which use less energy than conventional HFC-based systems, resulting in a double climate benefit.

This report also draws attention to a simple yet important step retailers should be taking to minimise their carbon footprint, namely the placing of doors on fridges. This straightforward measure has been shown to reap dividends, both in terms of customer satisfaction and in energy consumption. Putting doors on fridges is undoubtedly the biggest and easiest refrigeration-related energy saving measure a retailer can implement.

An exciting development this year has been the participation in our survey of three South African retailers. For the first time, we are witnessing retailers in the Southern Hemisphere leapfrog some of their European counterparts through their voluntary actions on HFCs. However, with HFC consumption predicted to grow by a staggering 800 per cent in developing countries by 2050,[3] it is clear that much more progress is required.

GREEN COOLING LEADERS

This year we are pleased to highlight an increase in the overall number of 'EIA Green Cooling Leaders'. The Green Cooling Leader title is awarded to retailers which show real commitment to HFC-free refrigeration, both in domestic and international stores.

New Green Cooling Leaders this year are Carrefour and South African retailers Makro and Woolworths. Those keeping the title from last year are Coop Schweiz, Aldi Süd, Migros, The Co-operative, Tesco and Waitrose. This year, Marks & Spencer and Royal Ahold have lost their positions as EIA Green Cooling Leaders, primarily because of their ongoing reliance on HFC/CO_2 hybrid technology and failure to move HFC-free refrigeration trials forward at an adequate pace, despite their commitments to going HFC-free from 2015. EIA accepts that HFC/CO_2 hybrid refrigeration can be used as a stepping-stone towards 100 per cent natural refrigeration but we are concerned that some retailers may see it as an end point in itself.

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KEY FINDINGS FOR 2013: UK AND REPUBLIC OF IRELAND

THE CO-OPERATIVE (HQ IN UK)

GOOD:

- HFC-free cooling now accounts for almost 23 per cent of total refrigeration used
- Has fitted hydrocarbon-based secondary refrigeration systems in five stores
- Has rolled out doors on fridges in over 200 stores

BAD:

- Incomplete survey

EIA GREEN COOLING LEADER

ICELAND (HQ IN UK)

GOOD:

- Trialling hydrocarbon integral fridges in five stores in the UK
- Trialling one chilled water system running on hydrocarbons
- Ammonia being used in 13 out of 15 distribution centres

BAD:

- No doors on chilled food, although most sales are frozen food
- No natural refrigerant use in food transport

LIDL (UK OFFICE)

GOOD:

- Testing new plug-in hydrocarbon chillers with a planned Europe roll out from 2015
- Use of frozen plates (cooled in distribution centres) has been rolled out to 10,000 delivery transport vehicles

BAD:

- Needs to extend its policy of putting doors on fridges to non-dairy chillers
- Majority of UK distribution centres still use HFCs

MARKS & SPENCER (HQ IN UK)

GOOD:

- 84 stores now using natural refrigerants, mostly HFC/CO_2 hybrids
- Expanding trial of HFC-free refrigeration systems to five locations
- Piloting a fleet of nitrogen-chilled delivery vehicles for 2014/2015

BAD:

- Needs to increase roll-out of HFC-free systems
- No progress on roll-out of doors, has been at trial phase since 2011

MUSGRAVE (HQ IN ROI)

GOOD:

- Fridges with doors are default specification for new stores and refurbishments
- Testing new plug-in hydrocarbon chillers

BAD:

- High use of HFCs in distribution centres

TESCO (HQ IN UK)

GOOD:

- Has rolled out natural refrigerants across 194 systems (a 30 per cent increase since last year), including 63 in Eastern Europe and 13 Asia
- Plans to extend commitment to use CO_2 across Europe
- In UK, 50 per cent of Express stores and over half of all new Metro stores have doors on fridges. Outside UK and China, 71 per cent of stores have doors on fridges
- All distribution centres are HFC-free

BAD:

- No doors on fridges in larger UK store formats
- No natural refrigerant use in delivery vehicles

EIA GREEN COOLING LEADER

WAITROSE (HQ IN UK)

GOOD:

- 36 per cent of stores now operating HFC-free systems (111 stores)
- Energy efficiency of water-cooled hydrocarbon installations up by 12 per cent from last year
- 95 per cent natural refrigerant use in distribution centres

BAD:

- No natural refrigerant use in delivery vehicles

EIA GREEN COOLING LEADER

KEY FINDINGS FOR 2013: REST OF THE WORLD

ALDI SÜD (HQ IN GERMANY)

GOOD:

- CO_2 transcritical systems have been rolled out as standard across 234 German stores, a 58 per cent increase since last year
- All new Swiss stores will be HFC-free, using an integrated CO_2 system offering cooling and heating
- HFC/CO_2 hybrid systems are now standard for all new Austrian stores and have been rolled out across 111 German stores
- 43 out of 51 distribution centres across Europe are HFC-free
- Uses renewable electricity in UK, Swiss and Austrian stores

BAD:

- No progress in UK roll-out of HFC-free refrigeration, despite being the country's fastest-growing supermarket chain
- Has not expanded natural refrigerant trial in refrigerated vehicles since last year

EIA GREEN COOLING LEADER

CARREFOUR (HQ IN FRANCE)

GOOD:

- Since last year, the number of stores using natural refrigerants has almost doubled to 133, including 36 using CO_2 transcritical systems
- Expects energy efficiency gains of 13 per cent in CO_2 transcritical pilot stores in Southern Europe
- Tentative plans to roll out CO_2 across Brazil, has opened two HFC/CO_2 hybrid stores there
- Has introduced doors on fridges in 173 stores in France

BAD:

- No natural refrigerant use in food transport
- Did not supply data from distribution centres
- Direct emissions from refrigeration are still disproportionately high

EIA GREEN COOLING LEADER

COOP SCHWEIZ (HQ IN SWITZERLAND)

GOOD:

- One-third of all stores (278) now using HFC-free refrigeration, keeping it well on-track to meet internal target to be HFC-free by 2023
- CO_2 transcritical refrigeration standard for all new and refurbished stores since 2010
- Installed Russia's first ever CO_2 system in 2014

BAD:

- High use of HCFC-22 across estate
- Only started to pilot doors on all fridges in 2014 (already using doors for fish products)
- No natural refrigerant use in food transport
- Minimal use of natural refrigerants in distribution centres

EIA GREEN COOLING LEADER

DELHAIZE GROUP (HQ IN BELGIUM)

GOOD:

- 61 natural refrigerant systems across EU and US estate, including 11 HFC-free systems
- Has made doors on fridges standard in all new stores, including US outlets, and fitted doors on fridges in all stores in Belgium and Luxembourg
- Currently piloting a fleet of 15 CO_2-refrigerated lorries in Belgium, with 60 per cent greater energy efficiency than HFC-based systems

BAD:

- Large number of installations in the US still using HCFC-22
- Needs to increase use of natural refrigerants in Eastern European and Asian estate

EL CORTE INGLÉS (HQ IN SPAIN)

GOOD:

- Has installed HFC/CO_2 hybrid systems in three per cent of stores, equating to about eight stores
- Using doors on fridges in 20 per cent of stores, with 40 per cent energy savings reported

BAD:

- Not yet trialling HFC-free systems, casting doubt over its ability to meet its Consumer Goods Forum pledge
- No natural refrigerant use in food transport
- Only one of 27 distribution centres is HFC-free

JERÓNIMO MARTINS (HQ IN PORTUGAL)

GOOD:

- Piloting three CO_2 transcritical systems in Poland and Portugal
- 105 stores now have doors on fridges, including 36 in Colombia, with plans to continue the roll-out
- Investing in the use of CO_2 snow to chill food in delivery vehicles

BAD:

- Two-thirds of refrigerants used in distributions centres are HFCs

KAUFLAND (HQ IN GERMANY)

GOOD:

- 99 stores using HFC/CO_2 hybrid systems
- High use of ammonia in distribution centres

BAD:

- Incomplete survey
- Not yet trialling HFC-free systems, casting doubt over its ability to meet its Consumer Goods Forum pledge

MIGROS (HQ IN SWITZERLAND)

GOOD:

- Has rolled out CO_2 transcritical refrigeration as standard across 227 supermarkets, accounting for 36 per cent of total stores
- Doors on fridges rolled out across 112 stores, with reported energy savings of 45 per cent
- Natural refrigerants account for 83 per cent of refrigerant used in distribution centres

BAD:

- No natural refrigerant use in delivery vehicles

EIA GREEN COOLING LEADER

WOOLWORTHS HOLDINGS LTD (HQ SOUTH AFRICA)

GOOD:

- CO_2 transcritical refrigeration in 24 stores
- Piloting use of nitrogen cooling in four delivery vehicles with one more under construction

BAD:

- Doors on fridges piloted in just two stores to date

EIA GREEN COOLING LEADER

MARKO (HQ IN SOUTH AFRICA)

GOOD:

- Using CO_2 transcritical systems in over 50 per cent of stores
- Plans to roll out CO_2 transcritical technology as standard for all new stores and all refurbished stores

BAD:

- Incomplete survey

EIA GREEN COOLING LEADER

PICK N PAY (HQ IN SOUTH AFRICA)

GOOD:

- Has HFC/CO_2 hybrid systems in 43 stores and three HFC-free stores
- Four of six distribution centres are HFC-free

BAD:

- Needs to invest further in HFC-free systems
- No doors on fridges and some freezers
- No natural refrigerant use in delivery vehicles

METRO (HQ IN GERMANY)

GOOD:

- Has committed to going HFC-free in all new and refurbished installations from 2015
- Has more than doubled number of natural refrigerant systems (both hybrid and HFC-free) to 20, adding five CO_2 transcritical and six HFC/CO_2 hybrid systems in 2013
- All seven of its distribution centres are HFC-free

BAD:

- Needs to start piloting natural refrigerant installations across its global estate
- Has few natural refrigerant installations compared to retailers of a similar size
- No natural refrigerant use in delivery vehicles

ROYAL AHOLD (HQ IN NETHERLANDS)

GOOD:

- 262 European stores now using HFC/CO_2 hybrids and three stores using transcritical CO_2, with one further CO_2 transcritical pilot system planned in the US this year
- Most European stores use doors on fridges, with plans to make this 100 per cent by 2015

BAD:

- Has not progressed its European pilot of three HFC-free stores since last year
- No natural refrigerant use in transport vehicles

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CHILLING FACTS: THE KEY ISSUES

"The transition to HFC-free refrigeration has so far caused no operational problems. Moreover, it has resulted in a significant amount of energy savings and GHG reductions."

Coop Schweiz

1. UPTAKE OF NATURAL REFRIGERANTS

As retailers become familiar with HFC-free systems and the energy savings they yield, we have seen an increase in the pace of the roll-out. Green Cooling Leaders Aldi Süd, Carrefour, Coop Schweiz and Tesco have rapidly increased their use of natural refrigerants since 2013. The dominant technology being deployed is transcritical CO_2. Other popular systems include water-cooled or air-cooled hydrocarbon systems and subcritical HFC/CO_2 hybrid cascades (see Glossary for full definitions). **EIA views the use of HFC/CO_2 hybrid systems as a potentially useful stepping stone towards HFC-free systems, but they should not be used as an end point in themselves.**

Big acceleration in CO_2 refrigeration roll-out among leading retailers

In its German stores, Aldi Süd has made impressive progress, with a 58 per cent increase in stores with CO_2 transcritical systems (total of 234 stores) and a 27 per cent increase in the number of stores with subcritical HFC/CO_2 hybrid systems (total of 111 stores). In Switzerland, the company has developed an HFC-free integrated CO_2 system providing heating as well as refrigeration which will be deployed as standard in all of its new Swiss stores. It is unclear to EIA why Aldi Süd is not rolling out HFC-free systems in Austria but instead relying on HFC/CO_2 hybrid systems. While parts of the company seem to be progressing well in their use of alternatives, Aldi Süd is failing to move forward in the UK where it currently has one trial HFC-free store which has been open for more than three years. The retailer reports that there is a "strong chance of further installations." However, given Aldi Süd's progressive use of natural refrigerants in Germany and Switzerland, it is not clear why all new UK stores are not HFC-free.

Other retailers increasing the pace of their natural refrigerant roll-out include global giant Carrefour, which has almost doubled the number of stores using naturals to 133 at the end of 2013, including 36 using CO_2 transcritical systems. It has also recently opened two HFC/CO_2 hybrid stores in Brazil. Coop Schweiz now has 278 stores using transcritical CO_2, up from 200 reported last year, and in early 2014 it installed the first ever CO_2 refrigeration system in Russia.

Major retailer Tesco has expanded its roll-out of natural systems to 194, adding an impressive 42 transcritical CO_2 systems in the UK alone, a result of its commitment that all new and refurbished Superstore and Extra stores and one-third of Express stores here will use CO_2. Tesco plans to extend this commitment to its European operations as soon as possible, having already rolled out five more of these systems in Hungary since last year. This retailer is focusing heavily on CO_2 transcritical technology but also appears to use hydrocarbons in Thailand and subcritical systems in China, although it is not clear if these are HFC/CO_2 hybrids.

Other retailers are focusing on subcritical HFC/CO_2 hybrid systems. African retailer Pick n Pay has 48 stores using CO_2 systems, three of which run on glycol and are completely HFC-free, while the remaining 45 use hybrid technology. German retailer Kaufland has more than doubled the number of HFC/CO_2 hybrid stores to 99 this year, up from 40 reported last year, while Royal Ahold has added another 35 stores using HFC/CO_2 hybrid systems to bring its total to 262 stores.

Other retailers report modest increases

In Europe, Delhaize now has 56 systems using natural refrigerants, including 10 HFC-free systems; it is yet to expand its trial of a hybrid HFC/CO_2 system in Greece. In the US, Delhaize has a further five natural refrigerant-based systems, including its first CO_2 transcritical system. Since its first CO_2 transcritical system was installed in 2010, South African retailer Makro has installed a further three in refurbished stores and seven in new stores, with a view to going HFC-free in all new stores and refurbishments. Marks & Spencer equipped a further eight stores with subcritical HFC/CO_2 hybrid systems this year; the retailer is currently testing transcritical CO_2 with positive results so far and plans to install two systems in stores later in 2014.

Although a key player in the European retail market, Metro has a relatively low number of natural refrigerant systems. However, during the past year it has more than doubled its installed base to 20, with five additional transcritical CO_2 and six subcritical HFC/CO_2 hybrid systems. Swiss retailer Migros reports a modest increase of 14 HFC-free stores this year bringing its total to 227.

However, with 36 per cent of stores using CO_2 transcritical technology, this retailer already has a comparatively large HFC-free estate. South African retailer Woolworths reports very positive experiences using CO_2 transcritical technology and now has 24 stores using these systems.

Just off the starting line

After highlighting our concerns regarding the lack of any natural refrigeration trials last year, this year, we are able to report some headway among participating southern European retailers, but progress remains frustratingly slow. El Corte Inglés is now using hybrids in three per cent of its estate, equating to about eight stores, while Jerónimo Martins has reported two CO_2 transcritical system trials in Portugal and one in Poland.

It's not all about CO_2!

Although CO_2-based technology is emerging as the dominant natural refrigerant alternative in supermarket refrigeration, chains operating smaller format stores are also realising the benefits of using hydrocarbons such as propane. Hydrocarbon technology uses integral systems which are factory assembled and therefore often easy to install and cheap to maintain. The simplest type of system is a 'plug and play' unit which contains the refrigeration system integrated within the unit, very similar in concept to a domestic fridge or freezer. Hydrocarbon integrals can also be water-cooled to increase the cooling capacity.

The Co-operative continues to lead the way on the use of hydrocarbon integrals for chilled food, adding this technology to a further 250 stores during 2013. It is also progressing in developing a hydrocarbon-based secondary refrigeration system which is now used in five stores. Lidl has made a significant move forward and is now in the final stages of testing a hydrocarbon plug and play unit for chilled food, with a view to a roll-out across its European estate in 2015. This could be a huge breakthrough for the industry as the availability of HFC-free integrals for chilled food has been very limited to date. Musgrave Group, which has also been using hydrocarbon integrals for frozen food is now conducting a similar trial to Lidl for its chilled food, although a roll-out schedule is yet to be defined.

We are pleased to note that after six years of encouragement from EIA, Iceland is finally trialling hydrocarbons

"All our new supermarkets and major refurbishments adopt the hydrocarbon water-cooled refrigeration systems as standard.... Our objective is to be free of HFC gases by 2020/21"

Waitrose

for chilled food in six stores, five of which are using plug and play systems with the sixth using a chilled water plant running on hydrocarbons to cool the cabinets.

After a very rapid roll-out reported last year, progress at UK retailer Waitrose has eased off slightly, with 111 stores using water-cooled hydrocarbon systems, up from 98 reported last year. On a more positive note, it has developed a second generation water-cooled natural refrigeration system with significant additional energy savings.

Distribution Centres

Table 1. provides an overview of the refrigerants used by retailers in their distribution centres. The use of natural refrigerants in warehouses varies dramatically amongst retailers, which is surprising as ammonia and CO_2 technologies are well established in this sub-sector. The continued use of HFC-404A (GWP 3,922) is entirely unnecessary and needs to be addressed, especially given the fast-acting EU HFC phase-down discussed in section 3.

HCFCs: bad habits are hard to shake

Eradicating HCFCs, a family of ozone-depleting substances targeted for elimination by the Montreal Protocol, should be a top priority for supermarkets. European legislation is ahead of the Montreal Protocol phase-out deadline, and from January 1, 2015 the use of HCFCs will be illegal in the European Union (EU). Yet there is a worryingly high amount of HCFC-22 still in use. Almost half of the refrigerant used to top up Carrefour Group's systems in 2013 was HCFC-22, amounting to 280

TABLE 1: REFRIGERANTS USED BY RETAILERS IN THEIR DISTRIBUTION CENTRES

RETAILER	REFRIGERANTS USED
ALDI SÜD	43 out of 51 are using ammonia (GWP 0)
CARREFOUR	Did not supply data
COOP SCHWEIZ	One third of refrigerant used is HCFC-22 (GWP 1,810) and remainder is mostly HFCs
THE CO-OPERATIVE	Did not supply data
DELHAIZE	In Belgium, half of refrigerant refills are ammonia In the US, most refills are HCFC-22
EL CORTE INGLÉS	One out of 27 is using ammonia, one uses CO_2 for low temperature, the rest use HFC-404A
ICELAND	13 out of 15 use ammonia, remaining two use HCFC-22 and HFC-407F (GWP 1,705)
JERÓNIMO MARTINS	35% of refrigerant used is ammonia, the rest is mostly HFCs
KAUFLAND	Mostly ammonia (did not supply specific data)
LIDL	Only supplied UK data: five use HFC-404a and four use CO_2 and ammonia
MAKRO	Did not supply data
MARKS & SPENCER	Six out of eight are HFC-free, using ammonia; remaining two use a mix of HCFCs and HFCs and are under review
METRO	All seven use ammonia
MIGROS	Natural refrigerants account for 83% of refrigerant used
MUSGRAVE	90% of refrigeration equipment uses HFC-404a, 10% uses ammonia
PICK N PAY	Two out of six use HCFC-22; remaining four use ammonia
ROYAL AHOLD	Did not supply data
TESCO	100% use ammonia
WAITROSE	95% of refrigerant used is ammonia
WOOLWORTHS	Two out of four use HFC-404a, with remaining two using HCFC-22

tonnes. As HCFC-22 is also a greenhouse gas with a GWP of 1,810, these emissions have the same impact on the climate system as over half a million tonnes of CO_2. Although much of this may be partly attributable to the fact that 35 per cent of Carrefour's sales area is located in developing countries, any HCFC-22 remaining in its European outlets must be targeted for rapid removal. Similarly, Co-op Schweiz is still relying on HCFC-22 to cool one-third of its distribution centres. In contrast, Pick n Pay, which is based in a developing country, has already converted two-thirds of its distribution centres to ammonia, with the remaining using HCFC-22.

2. IMPACTS OF THE EU F-GAS REGULATION

In 2015, new legislation to control fluorinated gases in the form of the F-Gas Regulation will come into force in the EU. It is by far the most ambitious HFC regulation in the world, setting out numerous use-restrictions including new product and equipment bans, by-product destruction obligations and a phase-down schedule. It will require businesses to rethink how they currently use HFCs and open up a huge market for HFC-free alternatives.

At the core of the new F-Gas Regulation is a reduction in the quantity of HFCs allowed on the EU market. This phase-down is fast-acting, with the first cuts due in 2016 and a stepwise reduction to just 31 per cent of the baseline eight years later. It is possible that the schedule will be strengthened in 2022 when it comes under regulatory review.

Use of high-GWP HFCs in existing refrigeration systems: the 'service ban'

With some minor exemptions, virgin HFCs with a GWP of 2,500 or more will no longer be permitted for servicing or maintaining refrigeration equipment with a charge size of 40 tonnes of CO_2 equivalent or more from January 1, 2020. This means that from 2020, virgin HFC-404A cannot be used to service equipment with a charge of just over 10kg of refrigerant.

However, retailers will have to act well ahead of 2020 in order to comply with the 37 per cent cut in HFC consumption required in 2018 under the phase-down schedule. The phase-down is based on CO_2-equivalence rather than metric weight, meaning that HFCs with a lower GWP will be more sought after by end-users; use of HFCs such as HFC-404A (GWP 3,922) will simply be out of the question once the cuts begin to take effect. As a major source of demand, the supermarket sector is expected to achieve a large proportion of the early cuts, especially since low-GWP alternatives are further developed in the supermarket sector than in air-conditioning, the other major consuming sector.

Given the vast amount of HFC-404A in supermarket systems, the most likely first step approach for existing systems will be to remove the HFC-404A and replace it with a 'drop-in' HFC with a GWP lower than 2,500. Marks & Spencer has already removed all HFC-404A from its refrigeration systems and replaced it with HFC-407A (GWP 1,990). Tesco has also been very proactive, stating that any existing stores not converted to natural refrigerants over the next four years will be switched from HFC-404A to HFC-407F (GWP 1,705). Waitrose has replaced HFC-404A with an HFC that has a GWP of 1,770 in 48 stores. Co-op Schweiz predicts that by 2020 most of its stores will be using CO_2 only.

However, some retailers do not seem to be aware of the need for quick action to address HFC-404A use. Worryingly, Metro says that it plans to phase-out HFC-404a by 2025, a full five years after the virgin HFC-404A ban. Aldi Süd has a company policy to phase-out HFC-404A in new units, but its plans to address existing systems are unclear. Other retailers are not specific about their plans. Retailers would do well to treat the service ban as an immediate *de facto* HFC-404A ban for any new equipment - for example, where replacing equipment currently using HCFC-22 - and put in place a schedule for phasing out HFC-404A from their existing estate as soon as possible.

EU equipment bans relevant to the supermarket sector:

Two placing-on-the-market (ie new equipment) bans will have an impact on retailers: the 2022 ban on HFCs (GWP ≥150) in hermetically sealed equipment and the 2022 ban on HFCs (GWP ≥150) in multipack centralised equipment, which has an exception for cascade systems where the primary circuit can use HFCs with GWP <1,500 (i.e. HFC-134a). By July 2017, the European

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ABOVE:
EIA Position Paper on HFCs in the Review of the EU F-Gas Regulation.

"Technological advances are boosting the market potential for HFC-free applications in supermarkets within Europe and beyond"

TABLE 2: EU EQUIPMENT AND USE BANS RELEVANT TO THE SUPERMARKET SECTOR

PRODUCTS AND EQUIPMENT	DATE OF PROHIBITION	GWP THRESHOLD
Refrigerators/freezers for commercial use (hermetically sealed)	2020	2,500
Refrigerators/freezers for commercial use (hermetically sealed)	2022	150
Stationary refrigeration equipment *(except equipment for cooling below -50°C)*	2020	2,500
Multipack centralised refrigeration systems (commercial use, 40kW or more)	2022	150
Exemption for cascade systems, where GWP 1,500 may be used for primary refrigerant circuit		

Commission must publish a report assessing this prohibition and could submit a legislative proposal to amend it, while a further review in 2022 could bring in additional bans and a strengthened phase-down schedule. With rapid breakthroughs for CO_2 technologies in warm climates and declining equipment costs, a prudent investment would be to roll out HFC-free stores exclusively from this point.

3. TECHNOLOGY FOCUS

Parallel compression technology

Historically, high summer temperatures have presented a considerable barrier to the roll-out of CO_2 technology throughout Southern Europe. However, the evolution of parallel compression technology could soon result in the limitless application of CO_2 refrigeration around the globe. The technology differs from existing transcritical CO_2 systems in that it becomes increasingly energy-efficient as ambient air temperatures rise due to the use of a parallel compressor which accepts CO_2 'flash gas' at a higher pressure. The world's second largest retailer, Carrefour, first announced it was trialling these systems in 2013 in several locations across Southern Europe, including Romania, Italy and Spain. The results so far are very promising; one store in Valencia (where the average summer temperature is 24.9°C)[4] is reporting energy savings of up to 13 per cent over an HFC-404A system.

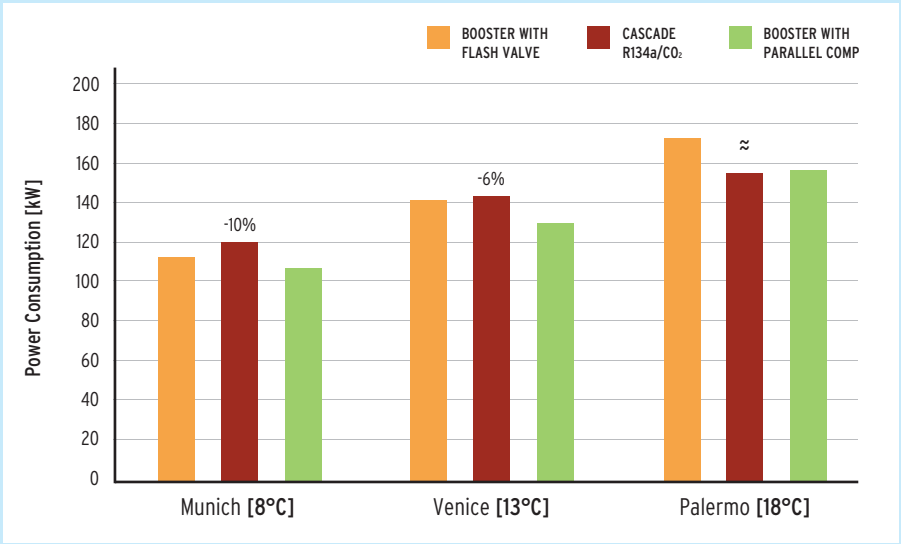
Figure 1 compares energy consumption between three types of CO_2 systems; the first shows a transcritical CO_2 system using a standard flash valve, the second an HFC/CO_2 hybrid system and the third a transcritical CO_2 system with a parallel compressor. Power consumption is compared for three European cities located in different temperature bands. The annual average temperature is shown in brackets. In Palermo, a city situated in the far south of Italy with a warm climate, the use of a CO_2 system with a parallel compressor improves the energy efficiency of transcritical CO_2 bringing it on par with the HFC/CO_2 hybrid system.

Following the success of the pilots, Carrefour has announced plans to install a further 10 such systems throughout Italy in 2014.[5] The retailer has already deployed CO_2 technology in its European stores but it is hoped these new systems will pave the way for a full-scale CO_2 roll-out in tropical regions, including Brazil.

Transport refrigeration

With the explosion in online grocery sales, the number of refrigerated transport vehicles in operation is expected to grow rapidly in the coming years.[6] Alarmingly, the majority of retailers surveyed this year continue to use extremely potent HFCs such as HFC-404A to cool their produce on the road. While the charge sizes may be comparatively small, this type of refrigeration is subject to high leakage rates because the units are often bounced around during transport. In 2012, EIA highlighted that retailers appeared to be putting this issue on the backburner, with almost all retailers entirely reliant on HFCs. Two years on, a handful of retailers are making some progress on this issue. Lidl is continuing to use specially designed eutectic plates,

FIGURE 1: ENERGY CONSUMPTION COMPARISON BETWEEN THREE TYPES OF CO_2 SYSTEMS
Source: Carel



cooled at its distribution centres, to keep perishable produce frozen on the road, without the need for an additional refrigerant.

After successfully piloting the technology in 2013, UK retailer Sainsbury's has invested in CO_2 refrigerated trailers. The technology is predicted to save the retailer 70,000 tonnes of CO_2e per year compared to its existing fleet which runs on HFC-404A.[7] Marks & Spencer has also informed EIA that it intends to purchase 25 nitrogen-cooled vehicles following a successful pilot of the system which yielded energy savings of 20 per cent compared with its existing trucks. While this represents only a fraction of Marks & Spencer's delivery fleet, EIA is hopeful that in time they will replace the company's existing systems which are predominantly reliant on HFC-404A.

Elsewhere in Europe, Delhaize has announced it will purchase 15 transportation trailers cooled with liquid CO_2 this year, having recorded energy savings of 60 per cent, and a 90 per cent reduction in carbon emissions compared to conventional HFC-based systems. Although it did not participate in EIA's survey, it is worth mentioning that SPAR Netherlands has shown that a full roll-out of these cryogenic systems is technologically and feasibly possible. The retailer announced it had converted 100 per cent of its fleet in 2013.[8]

Nitrogen-cooled transport containers are also being deployed in South Africa. Woolworths plans to deploy its fifth nitrogen-cooled container, having achieved savings of 3,000 tonnes of CO_2 equivalent per year over conventional systems in recent trials.

Although these developments are positive, EIA is disappointed that 60 per cent of retailers surveyed are yet to pilot any natural refrigerant delivery vehicles.

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Potential technology break-through for transport refrigeration

Producers of a new 'heat-hybrid' system, combining cryogenic cooling with waste heat recovery from a vehicle's engine, say that this technology will not only cut fuel consumption but that it will also remove the need for HFC refrigerants altogether.[9] Presented as an improvement on traditional cryogenic cooling systems, it uses liquid nitrogen to provide both cooling and some power, which reportedly makes the system far more efficient and cost-effective. Trials are currently ongoing.

4. ENERGY EFFICIENCY OF HFC-FREE REFRIGERATION

HFC-free systems are a double win for the climate

The benefits of HFC-free refrigeration extend beyond direct emissions reductions: efficiency gains from the use of natural refrigerant systems are also enabling retailers to save significant amounts on their energy bills. Commercial refrigeration currently accounts for one-third of the world's HFC consumption[10] and represents the largest share of a supermarket's energy demand.[11] Despite this, many retailers are losing out on potential savings through their continued use of inefficient HFC-based equipment.

Energy efficiency is one of our most effective weapons in the fight against climate change. In the EU, the European Commission recently put forward a proposal for an economy-wide 30 per cent energy savings target by 2030 and countries around the world are developing their own strategies to tackle this crucial objective.[12]

Against this backdrop, the value of switching to energy-efficient HFC-free refrigeration technology should be self-evident.

In Switzerland, where legislation bans the use of HFCs in most commercial applications,[13] CO_2 has become the refrigerant of choice. Coop Schweiz, which has already converted one-third of its stores to CO_2 refrigeration, reports energy efficiency gains of 25-30 per cent over HFC-based systems. Another Swiss retailer, Migros, is reporting similar gains with its new CO_2 systems, which use on average 33 per cent less energy than its HFC-based systems. In the UK, Marks & Spencer reports modest energy savings from both its HFC/CO_2 hybrid and HFC-free systems, but Waitrose's improved water-cooled hydrocarbon integrals have resulted in energy efficiency gains of by 34.2 per cent since 2012. Similarly, Musgrave's initial trials of hydrocarbon integral units for chilled food have so far reaped energy savings of 40 per cent compared to its previous centralised systems.

The benefits of better designed systems are not limited to refrigeration alone. A number of retailers including Lidl, Makro, Migros, Royal Ahold and Waitrose are also reporting the economic benefits of integrating refrigeration and heating systems in order to warm stores with recovered waste heat during winter months.

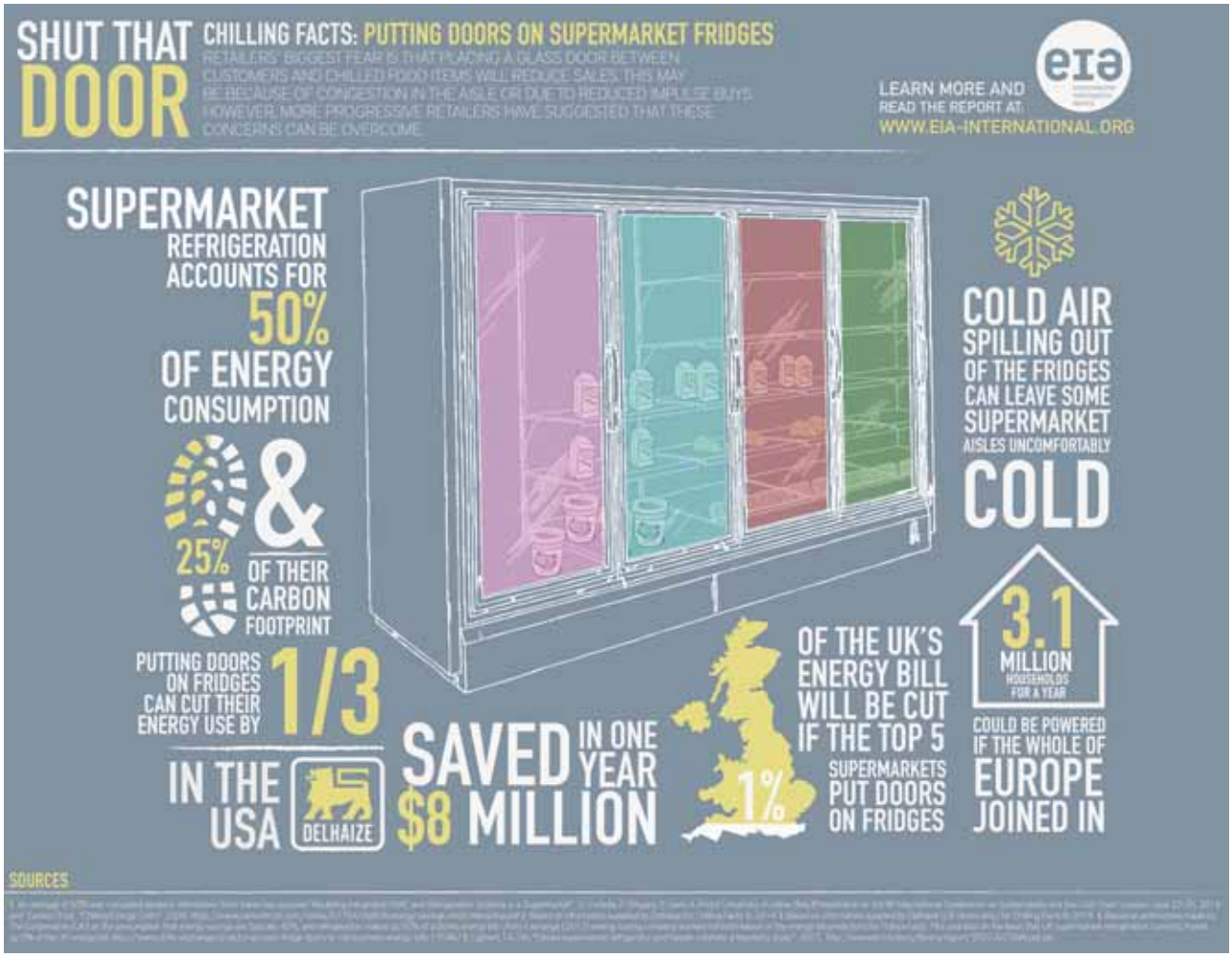
Energy efficiency of natural refrigerants in warmer climates

Concern about the energy efficiency of transcritical CO_2 systems in warmer climates has prevented many retailers from taking the plunge but the technology is now advancing at such a pace that it regularly outperforms HFC-based systems. As mentioned in the previous section, Carrefour's use of parallel compressors is reaping impressive energy savings in Southern Europe.

The roll-out of HFC-free refrigeration outside of Europe has not been without its challenges; Delhaize has reported slight energy efficiency penalties in its transcritical CO_2 installations in the US compared with its conventional HFC and HCFC-based systems. However, this may be due to the infancy of the trial and limited experience in working with this type of installation in the US. Cash and carry retailer Makro reports that its CO_2 systems generate energy efficiency returns of 35 per cent over conventional systems in its South African stores, aided by the use of recycled refrigeration condensate. Although subject to variation according to climate, a general trend of five per cent lower energy consumption in natural refrigerant systems is also reported by Tesco, which operates 13 of these systems across Asia and 63 in Eastern Europe.

It is clear that technological advances are boosting the market potential for HFC-free applications in supermarkets within Europe and beyond. The use of CO_2 in well-designed cabinets is continuing to outperform conventional HFC-based systems. Even in warmer climates where fluorinated chemicals have been the dominant technology for decades, we are now seeing a growing technological shift towards climate-conscious cooling. With the price of CO_2 installations continuing to drop year-on-year, EIA hopes more retailers will follow suit by investing in new, climate-friendly alternatives that don't cost the earth.

" Commercial refrigeration currently accounts for one-third of the world's HFC consumption and represents the largest share of a supermarket's energy demand"



5. DOORS ON FRIDGES – IT'S GETTING COLD IN HERE!

Many of us would baulk at the idea of leaving our fridge doors open at home yet we think nothing of strolling down chilly supermarket aisles as open refrigeration cabinets blast out freezing cold air. The impacts of this, which is standard practice in most supermarkets, are numerous. The most obvious drawback is that it takes a lot more energy for a refrigerator to keep food cool if it does not have a door. There are myriad other problems associated with open fridges, including food safety hazards and, from a human comfort perspective, the fact that many of us would prefer not to have to wrap up warm to buy our groceries! However, despite the clear benefits of equipping their fridges with doors, retailers are reluctant to adopt this simple measure, mainly because they fear it will reduce 'impulse buy' sales.

Energy savings

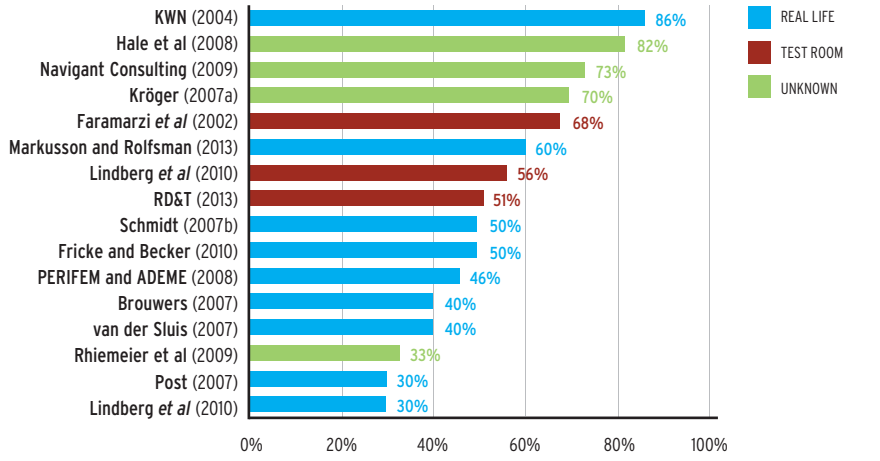
Refrigeration is the biggest source of demand for energy within a supermarket, usually accounting for about half a retailer's energy consumption[14] and about a quarter of a retailer's carbon footprint. Therefore, reducing the amount of energy used by these systems not only diminishes a retailer's carbon footprint but also reaps cost savings. The energy reductions associated with swapping from open to closed-door refrigeration systems are well documented and very impressive. A 2014 analysis of 14 separate studies, detailed in Figure 2, found that the majority of studies showed savings of over 50 per cent. [15]

Stores with doors

Table 3 details the extent to which surveyed retailers are using doors on fridges and the estimated energy savings associated with this measure. Adding doors is by far the biggest refrigeration-related energy saving measure a retailer can take, resulting in average reductions of about 33 per cent. This represents considerable cost savings; in the US, Delhaize estimates annual savings from its 800 stores with doors on fridges amount to US$8 million.

"Adding doors is by far the biggest refrigeration-related energy saving measure a retailer can take, resulting in average reductions of about 33 per cent"

FIGURE 2: REPORTED ENERGY SAVINGS ASSOCIATED WITH USING DOORS ON FRIDGES WHEN COMPARED TO FRIDGES WITHOUT DOORS
Source: Evans (2014)



Royal Ahold has been leading the charge with almost all stores now equipped with doors on fridges across Europe. Outside the UK, Tesco's use of doors on fridges is exemplary: in Turkey, over 95 per cent of its stores use them, closely followed by 84 per cent in Poland, 75 per cent in Hungary and over 86 per cent in Thailand. In the UK, it has committed to doors on fridges in its smaller format stores but not larger stores. In Belgium and Luxembourg, all Delhaize stores are equipped with doors on chilled food; however, it is not clear why this standard is not applied to its other European stores. Carrefour, El Corte Inglés, Jerónimo Martins and Migros have all increased the number of stores using doors on fridges since last year.

Retailers Aldi Süd, Marks & Spencer and Pick n Pay are less keen on adopting this measure. Aldi Süd has rejected doors on fridges, citing findings that doors negatively impact on energy efficiency during opening hours, and has instead focused on night blinds. Although it has run trials since 2011, Marks & Spencer is reluctant to move forward, primarily owing to a feared impact on sales. Pick n Pay is yet to adopt doors on fridges and still has a small number of upright freezers with no doors.

Alternative solutions used by retailers include Metro's chilled areas which are isolated from the rest of the store using walk-in doors. Waitrose's integrated system retrieves the cold air which spills out from the cabinets and re-uses it in areas of the building that would normally require air-conditioning.

Added Benefits of doors

Reduced refrigerant charge

The reduced electrical load on closed refrigeration systems means that the same cooling can be achieved with a smaller refrigerant charge size. This has very positive implications for the use of natural refrigerants such as hydrocarbons which, due to their flammability, are subject to stringent charge size limitations. By facilitating the use of HFC-free alternatives, doors on fridges further reduce the environmental impact of refrigeration.

Making supermarkets more customer-friendly

Cold air spilling from open cabinets reduces the surrounding temperature, leading to what is known as the 'cold aisle effect.' This can leave some supermarket aisles uncomfortably cold, especially in warmer months when customers are less wrapped up. In turn, this can reduce the amount of time customers are willing to spend in these areas and may have an impact on sales. By putting doors on fridges, supermarkets can make their chilled food areas more comfortable and thereby encourage customers to linger.

Good for sales

Retailers' biggest fear is that placing a glass door between customers and chilled food items will reduce sales. This may be because of congestion in the aisle or fewer impulse buys. However, more progressive retailers have shown how these concerns can be overcome. Carrefour has focused on addressing teething problems associated

TABLE 3: USE OF DOORS ON FRIDGES AND RESULTANT ENERGY SAVINGS REPORTED BY RETAILERS

RETAILER	NUMBER OF STORES WITH DOORS ON FRIDGES	ENERGY SAVING
ALDI SÜD	0	-
CARREFOUR	173 in France (3.6% of stores), more in other countries	18%
COOP SCHWEIZ	828 For fresh fish only	Data not supplied
THE CO-OPERATIVE	200	Data not supplied
DELHAIZE	Belgium and Luxembourg, 180 stores (100%). In the US, 800 stores	Energy saving equivalent to $8 million annually in the US
EL CORTE INGLÉS	52 (20% of stores)	40%
ICELAND	0	-
JERÓNIMO MARTINS	105 (46 in Portugal, 23 in Poland and 36 in Colombia) (3.6% of stores)	40%
KAUFLAND	Fridges containing meat have doors - do not specify how many stores	
LIDL	'Roll-in' milk chillers will be fitted with doors (two bays out of 25 per store)	Approximately 33%
MAKRO	Did not supply data	
MARKS & SPENCER	Small trial since 2011	35-40%
METRO	Unclear how many stores use doors, but if doors are not fitted then sealed separate chilled food areas are used.	Separated chilled area can reduce energy consumption by up to 30%
MIGROS	112 (17% of stores)	Up to 45%
MUSGRAVE GROUP IRELAND	Data not available as operated by franchises. Default specification for all new and refurbished stores is for doors on chilled and frozen cabinets	Approximately 30%
PICK N PAY	0	-
ROYAL AHOLD	855 (45% of stores)	Up to 25%
TESCO	UK: 50% of Express stores and most Metro stores. Larger stores do not have doors fitted; outside the UK (except China) over 2,500 (71%) stores have doors	Approximately 30%
WAITROSE	Installing doors in small stores in petrol stations	35%
WOOLWORTHS	Two stores (0.5%)	27%

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with restocking shelves and easy-to-use doors for customers and has consequently experienced steady sales. The Co-operative has reported positive customer perceptions such as a reduced 'cold aisle effect' and has also found that LED lights around doors have enhanced the customer experience, reporting that: "customers said it brought the product to life. In no places where we have put doors on fridges have sales gone down".[16] Another positive impact is a drop in shoplifting, further benefiting sales margins.

Food safety

Fitting chilled food cabinets with doors can lower the temperature inside the cabinet, reducing the risk of food poisoning from bacteria. Experts recommend that domestic fridge temperatures do not exceed 5°C,[17] however, in the commercial sector UK regulations allow chilled food to be held at or below 8°C.[18] These higher temperatures can have a big impact on food safety. For example, Listeria, a food poisoning bacterium that can harm unborn babies, grows nearly twice as fast at 8°C as it does at 5°C.[19] A 2008 study looking at the effect of putting doors on refrigerated food cabinets in a Swedish supermarket found that average daytime air temperatures inside chilled food cabinets decreased from 6.7°C to 4.7°C for meat and 7.2°C to 3.6°C for dairy.[20]

Food waste

Food waste is an enormous environmental and social problem. It is estimated that about one-third of food produced globally is discarded before it can be eaten, wasting vast amounts of water, energy and land used to produce it and costing about US$200 billion annually in industrialised countries alone.[21] While most food waste happens in homes, the total lifespan of food purchased from supermarkets is dependent upon how it is stored in the supermarket. By adding doors to fridges and keeping food cooler, supermarkets can help increase a product's lifespan even after it is sitting in your fridge at home.

Overcoming barriers to adopting doors on fridges

Slow progress

Despite the obvious benefits of doors on fridges and positive moves from some

retailers, there is general reluctance within the industry to make the switch. In 2013, the UK's Department for Energy and Climate Change (DECC) announced the creation of a Retail Refrigeration Task Force, targeting measures to reduce energy use within the sector. However, supermarkets' failure to act resulted in the watering down of the task force to a Retailer Energy Efficiency Task Force which has yet to see any commitment to adopt doors on fridges. A recent Department of Environment, Food and Rural Affairs (Defra) report has suggested "Despite the many benefits it may require more positive intervention from Government to encourage or insist on the use of doors on chilled displays."[22]

Future regulation

European regulators are currently considering proposals aimed at increasing the energy efficiency of commercial refrigeration units under the Ecodesign Directive. The legislation works by setting energy performance standards for equipment manufacturers to meet. If these standards are ambitious enough they will encourage the adoption of key energy-saving measures such as doors on fridges. However, current proposals fall far short of the ambition required and will allow many existing cabinets without doors to remain on the market indefinitely.[23]

6. SPOTLIGHT ON SOUTH AFRICA: HOW DEVELOPING COUNTRIES CAN LEAD THE WAY

Since 2008, EIA has expanded the scope of its *Chilling Facts* reports to cover a growing number of retailers, initially within the UK, and later across Europe. Having highlighted the progress of some retailers in emerging economies in last year's report, this year we are excited to include three South African retailers. EIA is impressed by the speed and extent to which these retailers are transitioning to natural alternatives, overtaking a number of European supermarkets along the way and putting them well ahead of their US counterparts. From 2008-2011, South Africa's second largest retailer Pick n Pay converted three of its stores to CO_2 and glycol systems in a project co-funded by the German Government and South Africa's Environment Ministry. EIA is encouraged to learn that it now has an additional 45 stores running on HFC/CO_2 hybrid systems. While Pick n Pay has highlighted the costs of natural refrigerant-based equipment as the main barrier preventing it going totally HFC-free, other South African retailers have reported a number of positive outcomes as result of their transition to naturals. For example,

"In South Africa, most of the leading retailers have started to move towards natural refrigerants"

Makro

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"2014 is crunch time for the CGF and its members to finalise preparations to begin phasing out the use of HFCs in 2015"

Woolworths, which has rolled out CO_2 transcritical technology across 24 of its stores, cites better temperature control, lower maintenance, a reduction in plant size and a substantial reduction in its carbon footprint among the benefits. What is more, employees are specially trained by suppliers and contractors to ensure safety standards are upheld when working with natural refrigerants. Despite the challenges posed by a climatically diverse estate, parts of which experience temperatures of up to 50°C, Woolworths has reported no operational problems with the CO_2 transcritical technology. By benchmarking itself against UK retailers, the company has been able to develop its ambitious policy on refrigeration ahead of many of its competitors on the global market.

EIA President Allan Thornton addressing members of the Consumer Goods Forum

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Following the installation of its first ammonia/CO_2 refrigeration plant in 2010, Makro has installed CO_2 transcritical systems in seven new and three refurbished stores, with a commitment to roll this out across all refurbishments from now on. Over half of the company's refrigeration systems are now reported to be running on 100 per cent HFC-free technology. By using reclaimed condensate from its refrigeration units, Makro has significantly improved its systems' efficiency when temperatures rise above 27°C. During these periods of high demand, up to 50 per cent of the plant's cooling capacity can be retrieved from thermal storage tanks which collect waste air over time.[24]

It is apparent to EIA that these South African retailers are ahead of the game and their ambitious voluntary actions should serve as a demonstration to other retailers across the globe that HFCs can no longer be viewed as a viable solution for commercial refrigeration.

7. CONSUMER GOODS FORUM PLEDGE

In 2010, the Consumer Goods Forum (CGF) made international headlines with its ambitious pledge to begin phasing out HFCs from 2015. Four years on, EIA's research shows that some CGF members have made significant efforts to realise this commitment while others are not yet out of the starting blocks.

In June 2014, EIA analysed CGF board members' progress towards the Activation Steps outlined by the CGF Secretariat in 2013, aimed at guiding retailers towards meeting their commitment.[25] Of the 25 retailer board members, EIA estimated that up to 16 have yet to make a public commitment to phase out HFCs in new installations from 2015. Just 18 retailers appeared to be piloting systems with natural refrigerants, indicating that numerous retailers are unprepared to begin phasing out HFC refrigeration in 2015. It is also important to note that, in some cases, a company's commitment to move away from HFCs only appears to apply to the country in which it is based. EIA considers that any such commitment should extend across a retailer's entire operations.

CONCLUSION

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The six editions of EIA's annual *Chilling Facts* report are testament to how quickly a market can change. Many of the challenges cited as hurdles to adopting HFC-free technology have now been addressed and leading retailers are rolling out climate-friendly refrigeration around the world, achieving a double win by slashing greenhouse gas emissions while making significant energy savings.

Now that we have clear regulatory signals in place in Europe, and pending elsewhere, HFC-free cooling technology will continue to flourish and early movers will be rewarded. The adoption of the EU F-Gas Regulation has already acted as a signal beyond Europe's borders and moves to eliminate HFCs are afoot in many other countries. Japan has recently announced its intention to phase down HFCs by encouraging a shift to lower-GWP alternatives.[26] Regulatory developments in the US also suggest that the market for HFCs will shrink, with legislation in the pipeline which could ban certain HFCs in the refrigeration, foam, aerosol and car air-conditioning sectors. These regulatory developments mean that companies which have not taken steps to phase out HFCs will be at a significant disadvantage unless they act swiftly.

This year's report has highlighted the pressing need for doors on fridges. It shows that despite remarkable energy savings (and associated cost reductions), retailers' fear of sales impacts has blocked action on this critical issue. The fact that other retailers are adopting doors on fridges suggests these fears are unfounded. Despite numerous opportunities to address this issue, many retailers seem unwilling to take the plunge and it is now time for policy-makers to step in.

"Many of the challenges cited as hurdles to adopting HFC-free technology have now been addressed"

RECOMMENDATIONS

RETAILERS

- **Commit to installing only HFC-free systems in all new stores and refurbishments, across entire estate, including their food transport systems and international operations**
- **Commit to a total phase-out by 2025 at the latest**
- **Fit doors on all chiller and freezer units as standard**
- **Remove any HFCs with GWP above 2,500 in existing equipment as a matter of priority**

GOVERNMENTS

- **Adopt ambitious energy efficiency standards which will encourage the uptake of doors on fridges**
- **Support an HFC-free transition in the supermarket sector to meet HFC supply reductions of the EU F-Gas Regulation**
- **Support the shift to HFC-free technologies by investing in increased capacity and skills development for the refrigeration servicing industry**

GLOSSARY

Climate-Friendly
This term refers to refrigerants with a low global warming potential.

CO_2
Carbon dioxide is the reference used to compare the impact of other greenhouse gases on the climate system in terms of their global warming potential (GWP). It is also used as a refrigerant.

GWP
Global Warming Potential. This defines the warming effect of a gas compared to the same mass of CO_2 released into the atmosphere. GWPs used in this report are based on a 100-year time frame.

Hybrid
Any system using two refrigerants for different parts of the cooling cycle; often these combine a natural refrigerant with an HFC, although sometimes both refrigerants are HFC-free.

Indirect emissions
Emissions from a refrigeration system resulting from the energy used to operate the system.

Integrals
A refrigeration system which is completely self-contained; integrals are also referred to as 'plug and play' or stand-alone cabinets.

Natural Refrigerant
A group of five refrigerants which commonly exist in nature: air, ammonia, carbon dioxide, hydrocarbons and water.

Subcritical CO_2 Cascade
Refers to a system using CO_2 in the low temperature cycle and another refrigerant in the medium temperature cycle.

Transcritical CO_2
Refers to a system using CO_2 in both the low and medium temperature cycles.

Water-cooled hydrocarbons
Hydrocarbons used in conjunction with water cooling to minimise the refrigerant charge.

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