ENVIRONMENTAL INVESTIGATION AGENCY

shecco

Summary: Technical Report on Energy Efficiency in HFC-free Supermarket Refrigeration

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Introduction

Cooling is necessary for the preservation of food, medicine, data and comfort and global demand is growing rapidly.[1] Current cooling technologies generally rely on fluorinated refrigerants (primarily hydrofluorocarbons (HFCs) and hydrochlorofluorocarbons (HCFCs)) that are greenhouse gases (GHG), often several thousand times more potent than carbon dioxide. In 2016, the world's governments agreed a global phase-down of HFCs under the Montreal Protocol on Substances that Deplete the Ozone Layer. The Kigali Amendment comes into effect in 2019 while the HFC phase-down under the EU F-Gas Regulation is already under way, significantly impacting market availability and prices of HFCs in Europe.

Cooling uses huge amounts of energy, often from fossil fuels, and is therefore a critical carbon emissions reduction challenge. The need to improve energy efficiency in the cooling sector is recognised in the Kigali Amendment and has been identified as the single largest action that can be taken to limit warming to less than 2°C under the Paris Agreement, representing about 40 per cent of the additional greenhouse gas reduction potential that can be realised by 2040.[2]

Commercial refrigeration is estimated to globally produce annual GHG emissions in the range of 1-1.3 billion tonnes of carbon dioxide equivalent ($GtCO_2e$), out of which direct emissions (from the refrigerant) range between 0.35-0.46 $GtCO_2e$ and indirect emissions (those associated with electricity use) range between 0.65-0.85 $GtCO_2e$.[3] It is therefore clear that tackling the climate impact of refrigerants must be coupled with addressing energy efficiency and energy sources of refrigeration systems. Given the relatively long lifespan of cooling systems in supermarkets, decisions being made now will impact the climate (and the bottom line for end users) for decades to come. To reap the highest rewards from investment in HFC-free technology, a rigorous integrated approach to equipment design and selection considering the entire needs of the store should be taken.

This briefing is based on a review of technical options for energy efficient HFC-free commercial refrigeration undertaken by shecco.[4] Based on interviews with market leaders, case studies and an extensive literature review, shecco's report demonstrates that there are energy efficient solutions for each type of application and store format, guaranteeing reliability, lower operation costs and proofing against future regulatory measures. Innovations such as parallel compression, ejectors, waterloop systems and optimised heat exchangers have made it possible to use efficient HFC-free systems in any climatic condition. The possibility to integrate heating and air-conditioning with the refrigeration system and harness the free rejected energy can, in appropriate market environments, further increase the overall energy efficiency of stores. Additional emission reductions can be achieved through the use of renewable energy, although this is not covered in this report.

There are also numerous ways to improve the energy efficiency of existing refrigeration systems, ranging from regular and thorough maintenance and servicing to improved controls and putting doors on display cases. Many supermarkets have already taken steps to improve the environmental impact of their cooling systems and are reporting positive results including reduced refrigerant leakage and lower energy bills through regular maintenance.

Food retailers should use the opportunity of the global HFC phase-down to simultaneously improve the energy efficiency of their refrigeration systems. Members of the Consumer Goods Forum (CGF) are key stakeholders in ensuring market demand for energy efficient HFC-free technology, encouraging development of new technology and system controls, sharing case studies and maintaining pressure on industry and policymakers to ensure the success of the HFC phase-down. Decisions concerning refrigeration systems must take into account the total life cycle cost (not just the initial upfront cost) and the full environmental impact. Making the right choices in terms of refrigerant, system design and maintenance practices will reap significant economic and environmental benefits in the future.

For further information, you can read the full report.

Climate impact of supermarkets

According to the International Institute of Refrigeration, 7.8 per cent of GHG emissions can be attributed to the heating, ventilation, air-conditioning and refrigeration (HVACR) sector.[5] While direct emissions from refrigerants account for around 35 per cent of emissions from cooling systems, the remaining 65 per cent are caused by indirect emissions coming from electricity consumption.[6] The proportion of indirect and direct emissions varies according to leakage rates, the Global Warming Potential (GWP) of refrigerants and electricity grid emission factors. Supermarkets consume approximately 3-4 per cent of the annual electricity production in industrialised countries and usually have one of the highest specific energy consumptions of commercial buildings (energy consumption per sales or total area).[7] Refrigeration systems consume 30-60 per cent of this total (depending on the climate, social habits and other factors).[8] It is clear that with the right system design, transitioning commercial refrigeration systems to more energy efficient HFC-free technology can significantly alleviate the burden on the climate, both in terms of direct and indirect emissions.

Using natural refrigerants will significantly reduce the direct emissions of a HVACR system. The most commonly used natural refrigerants today are ammonia (NH_3), carbon dioxide (CO_2) and hydrocarbons such as propane (HC-290), isobutane (HC-600a) and propylene (HC-1270, also known as propene). Water and air can also be used as refrigerants. Natural refrigerants do not deplete the ozone layer and make a negligible (or zero in the case of ammonia, water and air) contribution to GHG emissions. Natural refrigerants represent a 'basket of solutions' with different characteristics that can cover a wide range of temperature needs for different types of application. Natural refrigerant systems can also be very energy efficient, thus reducing indirect emissions.

Natural refrigerants do, however, have certain properties that need to be addressed through system design and carefully managed. CO_2 typically operates at a higher pressure than fluorocarbons and other refrigerants, requiring special components and skilled maintenance engineers. NH_3 carries a higher toxicity classification (B2), therefore its use is often restricted to unoccupied spaces or outside for example, it is often used in indirect systems in conjunction with other refrigerants (often CO_2) where the ammonia refrigerant is safely contained in an unoccupied closed room. Hydrocarbons are classified as highly flammable (A3) refrigerants, which means that charge sizes are limited according to equipment and application. The safety of hydrocarbons (as well as other refrigerants) is governed by international, regional and national standards. Many of these, however, restrict the safe use of hydrocarbons and need to be updated to account for recent technological progress.

HFC-free technologies available for new systems

Refrigeration systems typically used in food stores are centralised systems, condensing units and plug-in units, dependent on the size of the store and volume and range of chilled and frozen display and the quantity and type of products.

Supermarket refrigeration systems:[9]

Type	Application	Capacity (K/W)	Refrigerants typically used	Refrigerant charge (kg)
Centralised systems	Grocery retailers (discounters, supermarkets, hypermarkets, etc)	20 to > 1,000	HCFC-22 HFC-134A HFC-404A HFC-507A CO_2 HC-290 (propane) Ammonia	10 to >3,000
Condensing units	Stores, petrol stations, offices, hotels etc	5 to >25	HCFC-22 HFC-134A HFC-404A HFC-507A CO_2	1 to >5
Plug-in units	Stores, petrol stations, offices, hotels etc	0.1 to 2	HCFC-22 HFC-134A HFC-404A HFC-507A CO_2 HC-290 (propane) HC-600a (isobutane) CO_2	0.05 to 1

Centralised systems consist of a central refrigeration unit located in a machine room. Because centralised systems need to meet the demand of large stores and are made up of lots of pipes, they are a substantial consumer and, if not well-maintained, emitter of HFC refrigerants.

CO_2 is currently gaining market share in centralised systems. Europe currently has CO_2 transcritical systems in 14,000+ stores (about 12 per cent of the total market of supermarkets over 400m^2), South Africa has 102 stores and many countries including China, Indonesia, Colombia, Chile, Argentina, Brazil, Jordan and Malaysia are also starting to work with CO_2.[10]

Depending on the region, the technology used and a store's cooling needs, the total installation price for the entire CO_2 refrigeration system in the EU is currently 0-10 per cent higher than a conventional HFC system.[11]

Condensing units are typically found in medium and small stores where several display cabinets can be connected to the system to meet the needs of the store.

One of the most environmentally friendly alternatives currently available in this range is CO_2. Due to the slightly higher system complexity of using CO_2 in condensing units, initial purchase costs are higher than HFC units; however, actions to ensure increased efficiency during operation can mean that the life cycle cost is lower.

The use of CO_2 condensing units has been particularly popular in Japan where 3,100+ convenience stores (about six per cent of the total convenience store market) have been equipped with this technology. According to one end-user in Japan, CO_2 condensing units are 27 per cent more energy efficient than traditionally used HFC units.[12] Japanese CO_2 condensing units were installed in 12 Indonesian pilot stores and achieved energy savings of 20 per cent compared to HCFC-22, despite the proximity to the equator and warmer climate.[13] Furthermore, these systems are operating without ejector technology, leaving room for improvement in energy efficiency.

Hydrocarbons are also making headway in the condensing unit sector.[14] HC-290 units are being designed to deliver energy improvements of up to 30 per cent compared to HFC units.

A plug-in unit is a display case where the entire refrigeration system and components are integrated into the cabinet. The initial costs are much lower than centralised systems and their installation and maintenance is cheap and easy, with the option to replace a stand-alone cabinet upon failure. As the condenser heat is released directly to the sales area, this creates an additional heat load and can increase energy use if air-conditioning is required. To tackle the heat disadvantage, innovative waterloop solutions have been developed, integrated with hydrocarbon cabinets, mainly propane and propylene. There are currently more than 1,500 stores using this technology globally.[15] The heat generated is not released into the store, but instead is carried outside by a waterloop to a simple dry cooler. Some systems in place have achieved around 16 per cent better energy performance than similar HFC models.[16]

The most common natural refrigerant chosen to replace HFCs in plug-in systems is HC-290 and growth of 10-20 per cent is expected in the next 1-2 years in Europe, mainly driven by high customer demand and the need to comply with the EU F-Gas Regulation. There are currently more than 2.5 million hydrocarbon-based plug-in display cabinets in use globally.[17] Most manufacturers state energy efficiency gains of between 20-30 per cent, while a few indicated their HC-290 systems can be up to 40 per cent more efficient than HFC plug-ins.[18]

Plug-ins using CO_2 are also available and tests have shown 16 per cent energy usage reduction compared to HFC-404A units. The initial system cost however is eight per cent higher for the CO_2 unit, owing to the heat exchanger costs.[19]

Efficiency of carbon dioxide systems in warm climates

While the thermodynamic properties of hydrocarbons make them ideal refrigerants in high ambient temperatures, CO_2 faces challenges due to its low critical temperature (31°C). This has been largely overcome thanks to the introduction of parallel compression, ejectors, adiabatic cooling and mechanical sub-cooling.

Adding an adiabatic gas cooler to a transcritical system offers annual energy savings of 8-12 per cent. Adding parallel compression delivers 6-8 per cent savings and in combination with gas ejectors, savings can reach 8-10 per cent compared to a transcritical system without these enhancements.[20] Currently, initial costs of enhanced CO_2 transcritical systems are higher than conventional HFC-based systems; for example, the price of a system with ejector technology and parallel compression is up to 10 per cent higher than a standard CO_2 booster system; however, this is expected to change as the technology becomes more widespread (as has occurred with the standard CO_2 booster system).[21]

Parallel compression

Computer modelling concluded that parallel compression alone could improve the energy efficiency of CO_2 booster systems by as much as 10-15 per cent.[22] One retailer with an installation using CO_2 transcritical system with parallel compression has confirmed net electricity savings of 13 per cent compared to a former installation using R-22 in the south of Spain.[23] Furthermore, field measurement analysis has shown that air-conditioning delivery is 25 per cent more efficient when using parallel compression instead of standard flash gas by-pass.[24]

Ejectors

The most significant recent development for CO_2 refrigeration technology is the ejector system. Ejectors typically replace the high-pressure control valve, enabling expansion work recovery. This is particularly important for CO_2 systems operating in warm climates, where the expansion losses are high. Ejectors are used to recover part of the high throttling losses and convert it for pre-compressing CO_2 before the compressor's suction line (vapour ejectors) or to allow higher evaporation pressures in flooded evaporators (liquid ejectors).

A multi-ejector device can improve the system efficiency up to 20 per cent.[25] One manufacturer claims its new ejector rack can achieve 40 per cent energy savings compared to HFC systems and 30 per cent compared to CO_2 transcritical booster systems without ejectors.[26]

As of mid-2017, there are around 200 CO_2 transcritical booster systems running with either gas or liquid ejectors in Europe.[27] The estimated payback time for an ejector is between one and six years depending on the size of the supermarket.[28]

Mechanical sub cooling

Sub-cooling has a significant positive impact on refrigeration Coefficient of Performance (COP)[1] in CO_2 systems but it is a challenge to provide enough sub-cooling from the gas cooler on warm summer days. Some southern European supermarkets have installed a separate refrigeration system for sub-cooling the CO_2 cycle.[29] This technique is known as mechanical sub-cooling and hydrocarbons or NH_3 can be used in the sub-cooler for a climate-friendly solution. Computer modelling, laboratory tests and field measurements show significant CoP improvements for CO_2 systems applying mechanical sub-cooling in warm conditions.[30] However, the energy efficiency gains versus the expenses of using an extra unit for sub-cooling should be investigated in the design stage.

Adiabatic / evaporative cooling

Evaporative cooling is activated when outdoor temperatures reach 30-35°C and involves water being sprayed into the inlet air stream to the gas cooler. This may have limited applicability due to water availability, scaling and corrosion issues.[31]

Top left: Compressors on a CO_2 transcritical rack
Left: Ejectors in different sizes
Above: Adiabatic gas cooler (Güntner)

1. Coefficient of Performance denotes the ratio between energy usage of the compressor and useful cooling provided by an installation and is an expression of efficiency.

Role of components in improving energy efficiency in new and existing systems

Compressors

A compressor removes heat through the evaporator and is the most energy consuming element of a refrigeration unit. To ensure optimum efficiency a compressor should be set to the lowest condensing temperature possible and head pressure should be kept as low as possible.[32] Compressor performance can be further boosted by reducing size to better match store demand without compromising the capacity and efficiency. Smaller and more compact compressors require lower refrigerant charge.

Variable speed compressor technology utilises an inverter to control the cooling provided by the system and brings whole new levels of efficiency, comfort, reliability and versatility. Adding variable speed compressors can guarantee a 20-40 per cent efficiency increase which is further boosted by switching a system to hydrocarbons.[33]

The cost of CO_2 compressors in Europe is now on par or even lower than the cost of HFC compressors; however, cost is still an issue for variable speed technology, especially for larger equipment. Nevertheless, the energy savings offered by variable-speed compressors is greater than that of electronic expansion valves, at lower cost. Another key benefit for Original Equipment Manufacturers (OEMs) is that one variable speed compressor can cover a wide range of applications.[34]

Expansion valves

An expansion valve is the component which controls the amount of refrigerant flow to the evaporator, thereby controlling the heat expelled at the outlet of the evaporator.

Use of electronic expansion valves instead of thermostatic expansion valves allows adaptive adjustment of the control characteristics during operation. They can also operate with a lower pressure difference, allowing a more radical decrease in condensation temperature.[35] In a large Italian supermarket, energy savings of between 20 per cent (summer) and 35 per cent (winter) were achieved by using electronic expansion valves instead of thermostatic expansion valves for the medium temperature (MT) and low temperature (LT) evaporators.[36]

Heat exchangers (evaporators/condensors)

The performance of the heat exchanger can be improved by reducing the tube diameter thus decreasing the refrigerant charge, increasing system energy efficiency and lowering material costs.[37] Periodical cleaning of any heat exchanger surface improves the heat exchange and therefore reduces the energy consumption.

As the energy use of the compressor is dependent on the lowest evaporation temperature, all cabinets connected to the same compressor must be designed for the same evaporation temperature. Energy efficiency can also be harnessed by optimising evaporation and condensing temperatures. An evaporation temperature increase of 3°C reduces the energy use by approximately 3 per cent. Increased evaporation temperature can be achieved by increased evaporator area, and by using an Internal Heat Exchanger (IHX) installed after the evaporator. An IHX allows transferring superheat from the refrigerant leaving the gas cooler, to the refrigerant leaving the evaporator, which is then simultaneously sub-cooled. Increased evaporation temperature is also facilitated by using flooded direct expansion evaporators, enabled through the use of ejectors.[38]

For condensers, condensation temperature/high-side pressure should be lowered as far as possible. In CO_2 systems, gas cooler outlet temperatures can be lowered by using evaporative condenser/gas cooler cooling. Serial arrangement of gas coolers should be applied with respect to heat recovery and rejection to different heat sinks.

Controls

The efficiency of a refrigeration system depends only partly on the efficiency of the individual components. A significant increase in efficiency can come from the combined operating mode of the components in a unit and an installation as a whole.

Electronic controllers acquire a range of information from the units or the whole system (temperature, pressure, power consumption, occupancy, etc.), then process this information to ensure optimum control, managing activation or operation of the various components.

Compressor load shedding (strategically reducing power consumption during peak rate periods) in supermarkets can reduce energy demands by as much as 80 per cent for short periods of time.[39]

Cabinet design

As much as 75 per cent of a cabinet's cooling load is due to air infiltration, therefore glass doors or lids on cabinets can reduce the refrigeration capacity of a supermarket by up to 40 per cent.[40] Single, double or triple glazing of low emissivity may be used and, if possible, the glass doors/lids should be coated with a thin metal layer to reflect heat (infra-red) radiation, further reducing the energy consumption.[41] Adding doors can decrease daytime energy use by up to 60 per cent, while the interior storage temperature of the goods decrease 4°C in the daytime and 5°C at night.[42]

Measurements at a supermarket in Austria comparing the cooling load of open refrigerated multi-decks with those retrofitted with sliding glass doors resulted in energy savings of 86 per cent.[43]

Some retailers are concerned that cabinet doors will reduce sales. However, with glass doors, the air temperature in front of the cabinets is higher, thus reducing "cold aisle syndrome" where the lack of doors can make the aisle unnecessarily uncomfortable to the extent that the customer leaves the aisle, reducing potential sales. Based on observations from retailers, no losses in sales were documented after adding doors and lids.[44]

An alternative stop-gap technology increasingly used in the UK is Aerofoil™ technology which controls the direction of air flow, reducing cold air spillage by guiding the air streams into the air return grille instead of allowing the cold air to fall out of the fridge and be wasted.[45]

The addition of high-efficiency optimised fan motors can reduce energy consumption in new and existing cabinets by up to 70 per cent. Placing the evaporator fan motor outside the cabinet further reduces energy consumption.[46]

Role of heat recovery, renewables and storage in new and existing systems

Heat recovery

Supermarkets also often require heat, for space, processes and/or water. Yet all the heat removed by the refrigeration system (plus the energy used by the compressors) was historically wasted. Some or all of this heat is increasingly being recovered and used to provide heating, reducing gas or oil heating bills.

For high-grade heat recovery, a heat exchanger is installed, with the refrigerant on one side and the fluid to be heated on the other, reducing the cooling water or air needed by the condenser. If, for example, the boilers are heating water from 7°C to 80°C in winter, and the heat recovery system pre-heats this water to 20°C, this generates an 18 per cent reduction of the load on the boilers (and the corresponding fuel consumption). In addition, low-grade heat can also be used for underfloor heating.[47]

A supermarket's centralised refrigeration unit is a capital-intensive part of a building. Nevertheless, there are opportunities to integrate heating and air-conditioning into the refrigeration system, reducing or completely eliminating the need for additional heating and air-conditioning devices. The payback on an efficient heat recovery system can vary greatly depending on the region and the size of the supermarket. However, since all heat recovered is essentially free, the potential savings for the supermarket are significant. Depending on the boundary conditions and operation strategy, between 40-100 per cent of the supermarket heating demand can be met by heat recovery.[48]

CO_2 transcritical booster systems provide excellent opportunities for heat recovery. By increasing the discharge pressure of CO_2 and switching from subcritical to transcritical, the amount of available heat increases considerably. In addition, parallel compression in a CO_2 system allows integration of energy efficient air-conditioning with the refrigeration system. An auxiliary compressor provides the air-conditioning capacity. Such a solution can be characterised as an all-in-one integrated CO_2 solution, which can provide the entire or significant share of cooling and heating demand in supermarkets.[49]

A Danish supermarket was able to provide the entire heating demand of the supermarket (160kW cooling capacity) by replacing the gas heating system with heat recovery from a CO_2 transcritical booster system. The payback period for the heat recovery was less than five months.[50]

Some supermarkets could further capitalise on their recovered waste heat by feeding it into district heating systems or selling it to neighbouring buildings.[51]

Energy storage

Indirect emissions can be greatly reduced by storing energy, ideally integrating renewable energy (e.g. solar panels on roofs). The most polluting electricity tends to come from peak power plants and therefore from electricity consumed during peak periods. Thermal storage can help avoid these added indirect emissions and avoid paying the higher electricity prices during these times. Energy storage can shift large amounts of electricity load to off-peak times reducing total peak electricity demand by up to 40 per cent, resulting in significant savings.[52] Ice batteries can store cooling at night which is then used to power refrigeration systems during afternoon peak hours. They can also provide back-up cooling to reduce food spoilage during power outages. These batteries are plugged into existing refrigeration systems just like a display case.[53]

Emission reduction options for existing systems

Given the relatively long life of refrigeration systems, improving and maintaining the energy efficiency of existing systems is critical. Proper maintenance and leakage management should be a priority for new and existing systems, to avoid the leakage of HFC refrigerants and ensure optimised energy performance of the refrigeration system. Technicians must be sufficiently trained and certified and have training specific to different refrigerants and the latest technologies.

A well-scheduled and structured service and maintenance routine is the most cost-effective approach to ensure reliability and energy efficient operation of a refrigeration system. Proper maintenance and servicing can curtail up to 50 per cent reduction of performance over life of equipment.[54] This will lead to significantly enhanced performance with relatively small capital costs.

During a service visit, a refrigeration service engineer should: optimise compressor and evaporator set points (condensing temperature and suction pressure); optimise expansion valves; maintain and clean condensers and evaporators; and repair leakages. Refrigerant leaks are usually caused by material failure caused by vibration, damage due to frictional wear, improper material use, poor quality control, poor connections, corrosion and accidental damage.[55]

Further measures to improve energy efficiency for a refrigeration system (both new and existing) include:[56]

- Fan power adjustment (energy consumption of the fans can be reduced by up to 70 per cent);[57]
- Cabinet fan bearings should be inspected and lubricated according to manufacturer recommendations;
- LEDs inside cabinets (reducing the energy use by 60-70 per cent compared with the use of fluorescent lamps.) LEDs consume less energy especially when they are cool and reduce the heat load in the cabinet. When possible, place the lighting outside the refrigerated zone, or install reflectors or light conductors;[58]
- Improve insulation materials to avoid thermal conduction through walls which is responsible for approximately five per cent of the cooling load;
- Infrared reflecting shades and baldachins - Approximately 15 per cent of the cooling load of an open multi-deck cabinet comes from heat radiation exchange with the surrounding air;[59]
- Night covers on open cabinets can achieve energy savings of 25-40 per cent;[60]
- Anti-condensate heaters on display doors;
- Rim heating for chest freezers prevents condensation from ambient air and improves customer safety/comfort through increased edge temperature. A portion of this heat is conducted to the refrigeration unit and thus creates an additional cooling load. Demand controlled edge heating can reduce this cooling load by five per cent;[61]

- Correct cabinet loading and proper cabinet location - Overfilled open multi-decks consume up to six per cent more energy, while the temperature of the warmest products increases by 6°C;[62]
- Damaged or dirty door gaskets result in air leakage leading to energy loss and increased refrigeration load so they should be inspected and replaced if damaged. Display cabinet doors are subject to frequent use so their operation and sealing should be regularly checked;
- Dirty condenser and evaporator coils reduce air flow and cooling capabilities leading to higher energy consumption;
- Dirty refrigerated display cases are unhygienic, inefficient and can cause operating faults. They should be inspected regularly and cleaned when necessary;
- Monitoring, scheduling and reducing the number of defrosts required can decrease the energy consumed by the system. For new CO_2 refrigeration systems using flooded evaporators with elevated evaporation temperatures, defrosting once a week is sufficient. Alternatively, defrost on demand can be performed by observing the evaporation temperature (the evaporator temperature drops upon defrosting).[63] Furthermore, adequate defrosting flaps or socks, controlled by motors, can be used to interrupt the air exchange with the refrigeration room during defrosting;
- Visual inspection and testing with appropriate equipment should be carried out according to refrigeration principles, procedures, and safety requirements. Maintenance staff should be aware of the environmental impact of refrigeration systems and should understand their legal responsibilities under relevant regulations;
- Refrigerant charge should be checked regularly, as over- and undercharged systems have significantly reduced efficiency. Regular inspections should identify possible leaks which should be repaired immediately.

Monitoring and measurements

When choosing or maintaining refrigeration systems in supermarkets, several metrics regarding the energy performance, leak rates, life cycle cost and return on investment need to be calculated and monitored. These metrics are important to assess whether the systems are performing according to expectations, and to compare with other types of systems for new stores. A range of tools are available.[64]

The Life Cycle Costs (LCC) of a supermarket refrigeration system consider not only the investment costs but also costs for installation, operation including energy consumption, maintenance, downtime etc. In supermarkets, more efficient equipment is normally more expensive initially but consumes less energy, thus offering a lower LCC.

Conclusions

Eliminating HFCs is just one part of climate-friendly HVACR systems; energy usage must also be considered simultaneously. As the largest energy consumer in a supermarket, the refrigeration and air-conditioning systems must be a primary target for energy efficiency measures. Fortunately, the evidence from market leaders, case studies and an extensive literature review indicates that there are a variety of energy efficient HFC-free refrigeration technologies and no valid reason why the commercial sector cannot transition swiftly to such technologies. There are energy efficient solutions available today for any type of application and store format, guaranteeing reliable operation, lower operation costs and proofing against future regulatory measures. Innovations such as parallel compression, ejectors, waterloop systems, optimised heat exchangers and others have made it possible to use energy efficient HFC-free systems in any climatic condition. The possibility to integrate heating and air-conditioning with the refrigeration system and harness the free rejected energy further increases the overall efficiency of stores.

Legislative drivers to switch refrigeration systems away from HFCs offer an ideal opportunity for supermarkets to simultaneously improve their energy efficiency. Through careful planning and assessment of future-proof decisions, supermarkets can now be designed and installed with both the climate and the bottom line in mind. An obvious example of this is, where appropriate, the integration of heating and air-conditioning with refrigeration systems which use the free heat and cooling to cover needs that would otherwise have required additional energy systems.

Components, system and cabinet design and controls all play a vital role in the energy efficiency of a refrigeration system. Simple measures like cabinet doors can reduce the refrigeration load of a supermarket by up to 40 per cent. Given the relatively long life of refrigeration systems, well scheduled and structured implementation of both service and maintenance is the most cost-effective approach to ensure reliable and efficient operation of refrigeration systems (both new and existing). This will lead to significantly enhanced performance with comparatively low capital costs. To achieve the most efficient performance, continuous monitoring and optimisation of the refrigeration system needs to be conducted by trained engineers. To facilitate this work, a number of computational tools exist that can calculate important metrics such as energy costs, leakage rates, energy consumption and other useful indicators for the monitoring of refrigeration systems.

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