European Partnership for Energy and the Environment

Refrigerant choice:
New report reveals eco efficiency of supermarket refrigeration systems

Ever since the EU has committed to cut greenhouse gas emissions by 20%, food retailers have been under enormous pressure to reduce their carbon footprint. Refrigeration is part of the solution, as it accounts for some 50% of the energy consumption in a typical store. A new report by the British environmental consultants SKM Enviros evaluates different refrigeration solutions.

Refrigeration systems in supermarkets have been in the line of fire for quite a while. Not because of their energy consumption, but because of their direct f-gas emissions due to leakages. However, looking only at the refrigerant without taking into account the energy consumption of the system and other parameters such as climate can be quite misleading and detrimental to the environment. Indeed, energy consumption typically represents between 60 and 80% of the climate impact of a refrigeration system over its lifetime. A new study conducted by the British environmental consultants SKM Enviros and commissioned by the industry expert organization EPEE sheds light on the relative importance of the choice of refrigerant for the global climate impact of a refrigeration system and thus on the persistent myth that using one particular refrigerant is the universal remedy for supermarket applications.

Four Models, three Climate Zones

The primary aim of the SKM Enviros study has been to compare and evaluate the performance of different models of refrigeration systems as typically installed in European supermarkets. To that end, Enviros, together with a panel of industry experts, identified four typical refrigerant technology combinations including Model 1 (the base case: R-404A DX MT / R-404A DX LT), Model 2 (R-404A DX MT / Cascade CO_2 DX LT), Model 3 (R-404A indirect MT / Cascade CO_2 DX LT) and Model 4 (transcritical CO_2 DX MT / Cascade CO_2 DX LT).
Rated conditions for the 4 models were refrigeration capacities of 75 kW for the MT cycle and 20 kW for LT cycle.
The performance of the four models was then analyzed and evaluated taking into account their economical and ecological impact ("eco-efficiency methodology") in three typical European climate zones: Cold (Helsinki), EU Average (Strasbourg) and warm (Athens).

Hot and cold

The results of the study clearly show that all systems need more energy in warm climate conditions. Whilst the energy consumption of the R-404A base case (Model 1) and the R-404A / CO_2 cascade system (Model 2) are virtually identical, the indirect system (Model 3) consumes significantly more power than Model 1 and Model 2. Between Model 1 and the transcritical CO_2 system (Model 4), a cross-over in performance occurs at an ambient temperature of around 15°C. In cold climates (Helsinki) the ambient temperature is below this 15°C threshold for about 80% of the year, whereas this is the

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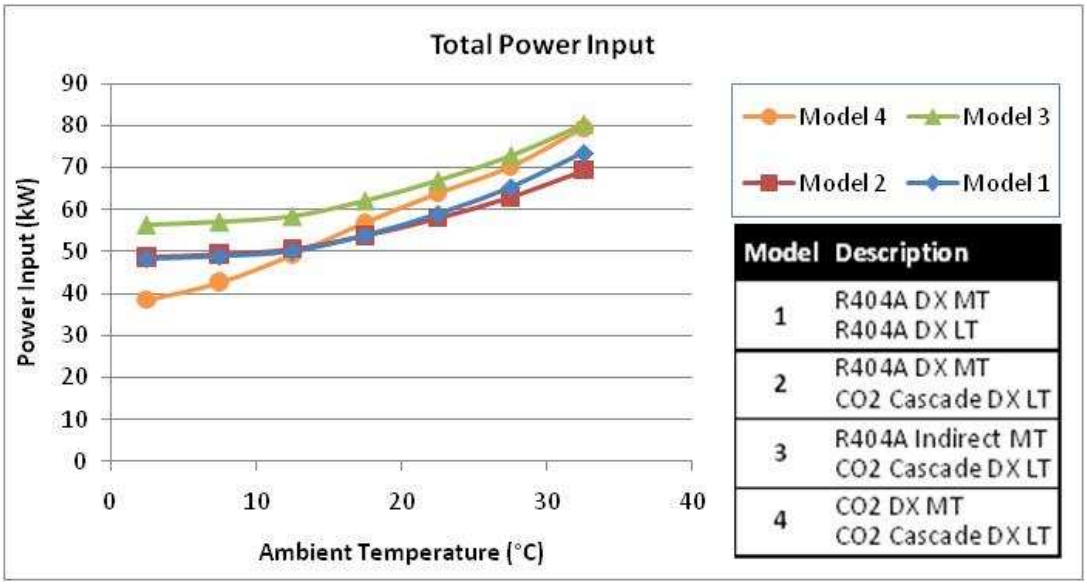
case in average climate conditions (Strasbourg) for about 65% of the year and in hot climates (Athens) only 37% of the year. In other words: CO_2 based systems are likely to be most energy efficient in average and colder climates, where they consume between 5% (average climate) and 10% (cold climate) less energy than the R-404A DX based systems.
Meanwhile, taking into account the high share of refrigeration systems in the total energy consumption of a supermarket, operators may choose not to adopt refrigerants with low GWP which may lead to higher energy cost, despite the benefit of lower direct greenhouse gas emissions due to refrigerant leakage.

Graph 1: Comparison of total power input (kW) for different Models at different ambient temperatures



Model	Description
1	R404A DX MT R404A DX LT
2	R404A DX MT CO2 Cascade DX LT
3	R404A Indirect MT CO2 Cascade DX LT
4	CO2 DX MT CO2 Cascade DX LT

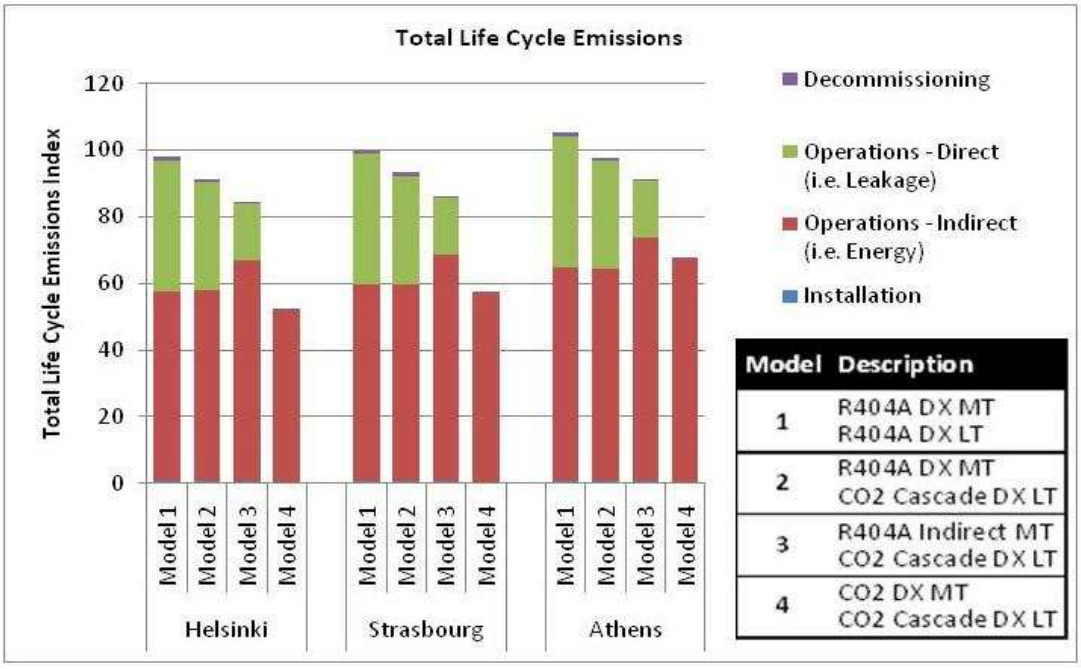
CO_2 systems are likely to be most suitable for average and colder climates, where they consume between 5% (average climate conditions) and 10% (cold climate conditions) less energy than conventional HFC systems. The cross-over in performance occurs at ambient temperatures of around 15℃.

Direct and indirect

Besides indirect CO_2 emissions due to energy consumption, leakage of conventional HFC refrigerants from supermarket refrigeration systems represents also a significant proportion of a supermarket's total greenhouse gas emissions. Analysis of a small sample of large supermarket chains in the UK, France and Germany indicates that refrigerant leakage can account for between 15% and 39% of their total equivalent CO_2 emissions. The level of leakage varies significantly between different systems, locations, companies and countries. New systems tend to leak less than old ones, due both to improvements in design and less wear on the system components. For typical R-404A

DX systems (Model 1), the study assumes a leakage rate of 15% on average of the installed refrigerant charge per annum, even though it may be significantly lower in some countries and significantly higher in others.
Other life cycle greenhouse gas indirect emissions which include emissions associated to the production of materials, manufacturing processes and installation as well as from decommissioning and disposal, contribute less than 2% to the total life-cycle emissions for all four models. Even if indirect emissions related to energy use dominate with more than 60%, direct emissions due to refrigerant leakage represent an important contribution to the global impact – in particular when the refrigerant R-404A with its high global warming potential (GWP = 3780) is used. Independently of the ambient conditions, Model 1 therefore results in the highest annual emissions of greenhouse gases whilst Model 4 shows the lowest greenhouse gas emissions, independently of the ambient conditions. This points to a reduced leakage rate as a major improvement opportunity for HFC systems.

Graph 2: Total life cycle emissions by Model and ambient conditions



Even if indirect emissions dominate with more than 60%, direct emissions due to refrigerant leakage have an important influence on the overall performance result, especially in case of HFCs with a high GWP. Therefore, reducing the HFC refrigerant leakage rate plays an essential role.

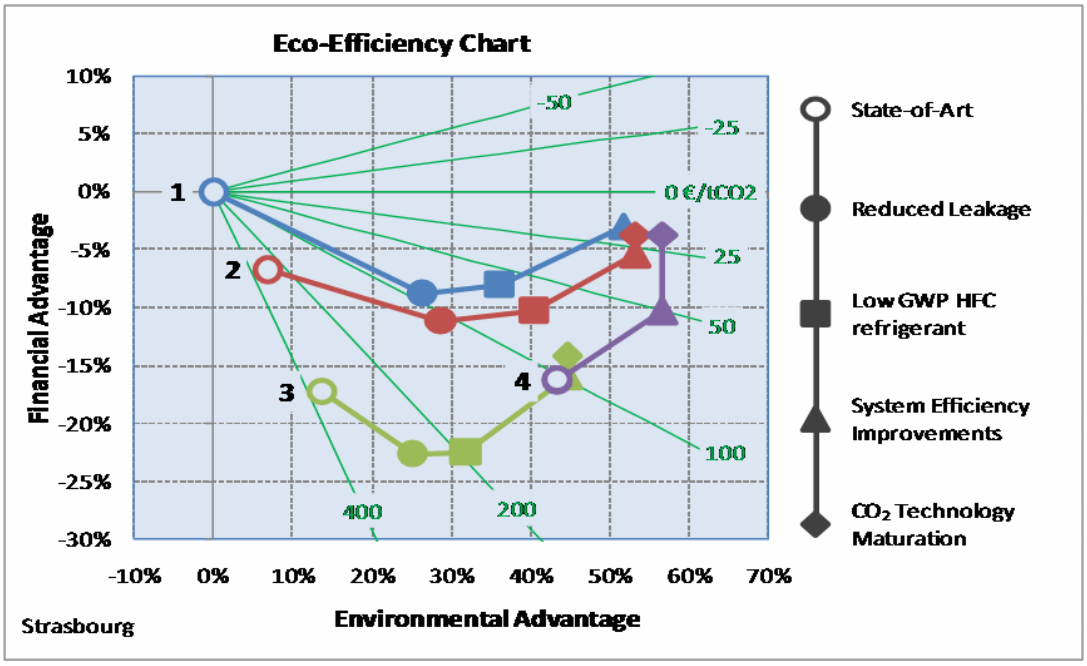
Ecological and economical
The eco-efficiency methodology used by SKM Enviros allows also to compare the global performance of the four technologies from an economical perspective. Costs for energy, maintenance, refrigerant and capital were combined to give an annual average life cycle cost. As energy consumption and capital (investments in the compressor packs, display

cabinets and site installation) have the highest impact on the total life cycle cost, model 4 suffers from its early stage of market launching. However, as the market for CO_2 refrigeration systems matures, their costs will decrease and the actual financial premium will drop. On the other hand, maintenance costs for non efficient HFC systems (especially old systems prone to leakages) are likely to increase significantly with the enforcement of the European F-Gas Regulation 842/2006 requiring increased maintenance and management efforts.

Today and tomorrow

SKM Enviros plotted the results of total life cycle cost and total life cycle emissions on the "eco-efficiency" chart next before evaluating different improvement opportunities starting from the non-optimized base case Model 1. The result is not surprising: As of today and in average climate conditions (Strasbourg), Model 1 has the lowest financial impact (i.e. life cycle cost) but the highest environmental impact (i.e. life cycle emissions) whilst Model 4 has the lowest environmental impact (-43%) but a significantly higher financial impact (+17% compared to Model 1).
Obviously, these findings are not static but will evolve over time and create improvement opportunities. SKM Enviros evaluated different scenarios and the results are impressive:
By reducing refrigerant leakage, using lower GWP refrigerants (e.g. R-134a), making installations more efficient and giving technology more time to mature, greenhouse gas emissions of models 1, 2 and 4 can be reduced by around 50 to 60% with an increase of life cycle costs by only around 5% – at roughly 20 € per ton of CO2 saved. In other words: the gap between the different refrigerant solutions can be closed and the choice of refrigerant will then make no significant difference any longer.

Graph 3: Tackling direct (refrigerant) and indirect (energy associated) emissions



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Relative to the original "state-of-the-art" R-404A DX system (Model 1), Model 2 and Model 4 offer reductions in greenhouse gas emissions of around 50 to 60%, for an increase of life cycle costs by around 5% – at roughly 20 € per ton of CO_2 saved.
Conclusion: *the industry needs time to tap the full potential of the F-Gas Regulation for HFC systems, to mature for CO_2 based systems and to be fully optimized for all considered technologies.*

Time is of the essence

Whether HFC systems or CO_2 based systems are considered, the retail sector and refrigeration industry need time to reach the best level of performance and minimal climate impact of their systems. This study demonstrates that this can be achieved through technological optimization of all considered technologies: either by improving HFC based refrigeration systems in line with the requirements of the European F-Gas Regulation or via the maturation of CO2 based refrigeration systems. When these conditions are fulfilled, the ecological and economic impacts of all investigated Models will come so close together that the refrigerant itself will hardly make the difference and further energy efficiency optimization will continue to be a way of further improving the performance. It is therefore up to the refrigeration industry to show its real potential and willingness to reach the objective of further reducing the global climate impact of their systems and to the legislators to understand that Rome wasn't built in a day.

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The full study is available upon request at: secretariat@epeeglobal.org

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The European Partnership for Energy and the Environment (EPEE) is the de facto voice of the heating, cooling and refrigeration industry in Europe. It represents a broad-based group of responsible companies, national associations and European associations active in the European heat-pump, air-conditioning and refrigeration industry. It was formed in September 2000 to contribute to the development of effective European policies to increase energy efficiency and reduce greenhouse gases from the use of refrigerants. Further information can be found on-line at www.epeeglobal.org.