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Comparative Assessment of the Climate Relevance of Supermarket Refrigeration Systems and Equipment

Summary

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COMPARATIVE ASSESSMENT OF THE CLIMATE RELEVANCE OF SUPERMARKET REFRIGERATION SYSTEMS AND EQUIPMENT
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After the entering into force of EU regulation (EC) No. 842/2006 and the EU directive 2006/40/EC, refrigeration systems in supermarkets remain the last big subsector and the strongest emission source of fluorinated hydrocarbons (HFC) in Germany.

With regard to existing improvement possibilities for components, technologies, and their application, the EU-political process up to now refrained from a use ban of HFCs in refrigeration systems and other applications. A central point for this decision was that it was not clear for certain important applications if comparable reliability, energy efficiency, and safety standards could be provided with HFC free technologies at adequate costs.

Though, a differentiated bundle of obligations for the operation, the maintenance, and the disposal of all bigger refrigeration systems was included into Regulation (EC) No. 842/2006. With regard to the ongoing review of the regulation the question positions itself whether this approach of the so-called "refrigerant containment" is sufficient as a sole measure for the reduction of HFC emissions, or whether use bans on the basis of further experience with alternative technologies seem more appropriate.

However, in wide parts of Europe and Germany the following problems arise for the majority of relevant refrigeration systems: Due to missing legal obligations to date, only limited experience with the use of HFC free refrigerants exists in the very cost-conscious retail market, so that a comprehensive and accurate data basis of energy efficiency and economics for systems operating without fluorinated greenhouse gases often does not exist. However, this is again necessary to justify further restrictions for the use of HFCs if necessary.

At this point the present survey starts. In the first part the survey offers a comprehensive overview of HFC free refrigeration systems for supermarkets offered and applied in Europe. The second part offers information about the energy efficiency and economics of the HFC free systems in comparison to conventional systems on the

basis of the Total Equivalent Warming Impact (TEWI). In the third part technical, economical and structural barriers for the expansion of the future insertion of natural refrigerants are identified. Furthermore, steps are described for near- and mid-term options for overcoming market launch barriers. Additionally, recommendations for potential subsidies for the promotion of HFC free refrigeration systems are developed.

The fourth part of the project consisted in the hosting of an international conference named "Co_2oL Food - Climate Friendly Refrigeration in Supermarkets" on the 22nd and 23rd of May, 2007 in Berlin. The event with more than 140 participants is not an object of this final report. The most important result of the conference was the clear trend in the retail sectors as well as technology suppliers towards environmentally friendly refrigeration concepts. Further results and presentations of the conference are available for download at: http://www.umweltbundesamt.de/produkte/fckw/CO_2ol.htm.

Market survey

The first part of the report contains a market survey of supermarket refrigeration systems that are completely or partially operated with HFC free refrigerants, including information on their actual market penetration in the EU. Beside the respective relevance of the technology in the market, it is also displayed to what extent appropriate operational experiences exist. In a detailed data compilation, the so-called technology data sheets, 30 main characteristics for *decentralized plug-in units*, *condensing units* and for *central multiplex systems* are given. These characteristics provide information on equipment data, refrigerant losses, energy consumption, life cycle costs, market share, operational experiences, and suppliers. Furthermore, all currently relevant refrigerants are described with regard to their physical properties, with an in depth look at their cost effectiveness and climate relevance for the food retail sector. The data compilation is based on an extensive literature research of scientific technical literature as well as on numerous interviews with manufacturers, suppliers, and retail representatives.

Beside the description of the equipment technology itself the market survey also offers an overview of the relevant store categories in which the respective technology is used, substantial details on energy saving measures, a compilation of leakage rates of

supermarket refrigeration systems, as well as examples of already existing F-Gas regulations in selected European countries.

TEWI Analysis & Validation

This part of the report gives an overview of the emissions from refrigeration systems used in supermarkets and indicates abatement costs which arise by conversion of conventional systems to new systems with natural refrigerants.

The effect of a refrigeration system on global warming is described by the Total Equivalent Warming Impact (TEWI). The TEWI value of a refrigeration system describes according to DIN ISO 378-1 the sum of indirect emissions of the equipment from its energy consumption and direct emissions caused by refrigerant losses.
Due to the high amount of technical possibilities and the heterogeneous German market scenery, the model technologies to be examined were selected during two expert's meetings together with system providers and retail representatives for the following three store categories: discounter, supermarkets, and hypermarkets.
Great emphasis was put on a trusted empiric data base for the calculation of the TEWI analysis. Hence, refrigerants supplies and energy consumptions of the examined reference technology were determined in cooperation with several German retail chains. As reference technology a central multiplex system on the basis of R404A is defined for all three store categories. R404A is currently most often used in the German food retail sector.
Due to several factors, as for example weather conditions, equipment age, and consumer behavior, the energy consumption of refrigeration systems tend to considerable variability. Also one cannot extinguish the same typical refrigerant charge in every single system. Therefore a detailed uncertainty analysis was carried out with the help of Monte Carlo simulations. The Monte Carlo results clearly show that emissions of the examined model technologies in spite of high uncertainties vary only in a certain bandwidth, what allows robust comparisons of the respective climate impact of each model technology.

Other important input factors for the calculation of TEWI analyses are refrigerant leakages and losses. Refrigerant losses appear at all refrigeration systems. The extent of the losses caused by leakages depends on the complexity of the refrigeration

system, the operating conditions, the quality of maintenance, and many other factors. The differences of reported leakage rates are accordingly high. To illustrate refrigerant losses adequately, the TEWI analyses are calculated for three different policy scenarios. In each policy scenario fix leakage rates according to political tightness restrictions are assumed. In practice higher leakage rates can appear because of unforeseen system damages through which considerable amounts of refrigerant escape. This case is examined in a sensitivity analysis separately.

On the basis of the TEWI results specific abatement costs are calculated for all selected model technologies. The calculated abatement costs show the costs per ton of avoided CO_2 equivalent relating to the reference technology. Abatement costs are also calculated for each different policy scenario, because costs as well as emissions vary according to tightness obligations.

As a result of the TEWI analyses it becomes clear that new CO_2 systems within the scope of all considered uncertainties significantly provide the environmentally superior solution compared to systems using R404A. For discount markets the significance does not persist for high leak tight systems (annual refrigerant loss of 2.65%) any more. The abatement cost calculation also shows, that the placing on the market can be realized at the moment still at rather high specific abatement costs, however, these will clearly decrease with increasingly stricter tightness obligations for conventional systems with HFCs and cost degression for systems with natural refrigerants in the near future. Table 1 summarizes the quantitative results from TEWI analyses and the abatement cost calculations for all examined technologies in a transparent way.

Particularly should be pointed out that in case of higher refrigerant losses as assumed in the policy scenarios, HFC free technologies offer considerably higher emission reduction potentials. In that case also abatement costs will decrease clearly for alternative HFC free technologies. Therefore the influence of refrigerant losses on emissions and abatement costs is analysed in a separate sensitivity analysis.

Table 1: Combined overview to TEWI results and abatement costs for different tightness scenarios and model technologies

		Tightness scenario 1 (11.65%)	**Tightness scenario 2** (6.15%)	**Tightness scenario 3** (2.65%)
Discounter				
I	**Reference system *)**	B-	B-	B-
II	R134adir. MT	A +	A +	B +
III	ind. R290 MT	A-	A-	B ++
IV	dir. 744 MT	A-	A-	B ++
Supermarket				
Ia	**Reference system *)**	B-	B-	B-
Ib	R134a MT+R404A LT	A-	A-	A-
IIa	R404A MT+R744 LT	B-	B-	B-
IIb	R134a MT+R744 LT	A-	A-	A-
III	ind. R717	A-	A-	B-
IVa	R717 / R744 MT+LT	A-	A-	A ++
IVb	R290 / R744 MT+LT	A-	A-	A ++
V	dir. R744	A-	A-	A +
Hypermarket				
I	**Reference system *)**	B-	B-	B-
III	ind. R717	A-	A-	B-
V	dir. R744	A-	A-	A ++

***)** R404A direct evaporation system

Coding of the evaluation

Climate balance:
- **A** : Significantly superior to the reference system
- **B** : No significant difference to the reference system
- **C** : Significantly inferior to the reference system

Cost-effectiveness:
- **++** : negative abatement costs
- **+** : abatement costs <=50 Euros per ton CO_2 equivalent
- **-** : abatement costs > 50 Euros per ton CO_2 equivalent

The results show that, with regard to future investments in new refrigeration systems, beside the cost question also the right choice of refrigerant will increasingly matter. The actual public discussion about men made climate change shows that sustainable and environmentally friendly management becomes more and more important and also increasingly becomes a strong sales argument.
By applying the use of natural refrigerants in new systems certain retailers step towards environmentally friendly refrigeration already today, because thereby they can avoid double investments initially for compliance with higher tightness standards and then later for the installation of new technology with natural refrigerants.

A further strengthening for the use of fluorinated greenhouse gases is to be expected in Germany as well as throughout Europe during the next years. This is reflected for example by the “integrated energy and climate program” of the German Federal Government, published in August 2007, as well as in article 10 of regulation (EC) No. 842/2006 on certain fluorinated greenhouse gases, which foresees a review of the regulation by July 2011.

Barriers and Improvements

This chapter analyses the state of the art of refrigeration systems with natural refrigerants available in the market. A special focus is put on the further development of the CO_2 technology, because equipment and component manufacturer increasingly work on the market introduction and the improvement of the systems. Besides, essential barriers are indicated which prevent the use of new HFC free systems and complicate their expansion in the food retail sector. Here is to be distinguished between technical and economical barriers. Big technical barriers are the availability and the level of development of important components, above all for equipments with carbon dioxide. Due to the thermodynamic properties of CO_2, e.g. compressors, valves, and heat exchangers have to be entirely new designed. Currently, a large part of necessary components has not yet matured finally and is not available in the necessary width to carry out a quick introduction of the new technology in the market. As a consequence also economical barriers arise, because due to the missing readiness for the market of some components still no serial production could be reached so that prices for certain components stay high. This chapter indicates how economical and technical barriers

can be overcome by a growing demand for CO_2 systems from the retail sector in the coming years.

For the support of an increased future use of natural refrigerants in the retail sector two possible measures for public funding are suggested. A financial supporting measure is suggested for the promotion of the demand for new systems with natural refrigerants within the scope of the “integrated energy and climate programme” of the German Federal Government. This demands a reduction of the German fluorinated greenhouse gas emissions of about 8 million tons of CO_2 equivalents under article 23. For the implementation a subsidy payment is planned to cover the extra costs for refrigeration systems in the food retail sector: This subsidy should be paid only under exclusive use of natural refrigerants and should intend a progressive rate for new systems in new or existing markets or for the substitution of an old R22 system. With a suitable subsidy volume and a change over to batch production of CO_2 systems the market launch can be made substantially easier.

The second funding measure is a competition. It should award a prize to the environmentally friendliest German supermarket. Within the scope of the competition new refrigeration systems with natural refrigerants and a low TEWI value should be awarded. The award of the competition can be a combination of public-relations symbolism as a main aspect and a (limited) financial incentive. Therefore an award in the form of a quality label, which also can be used for PR and marketing purposes, and a financial bonus, should be assigned to the winner.

The dimension of the suggested subsidy programme is likely to bring movement in a market whose dynamics is presently still limited by the existing cost thresholds of different actors (component manufacturers, system manufacturers, retailers). The competition additionally raises the attention for the climate relevance of refrigeration systems in the food retail sector, and helps to improve the public acceptance and demand for climate friendly refrigeration systems as well as their "image factor".

Additionally the energy saving potential of refrigeration systems through the implementation of cover sheets is analysed. The continuous covering of refrigeration units with sliding lids (chests) or doors (shelves) is considered as an important energy

saving measure. The reduction potential is estimated up to 40 percent of the energy consumption compared to an open refrigeration unit. The fitting and retrofitting of refrigeration units, with continuous covers started about ten years ago. Beside the energy savings the better temperature guarantee for the chilled goods is a determining motive for the covering of refrigeration units. To be able to better estimate the meaning of this potential, the status of the current coverage quota in Germany was assessed by questioning relevant food retailers.