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Fluorinated Greenhouse Gases in Sweden

Review of Methodology and Estimated Emissions Reported to the UNFCCC and the EU monitoring Mechanism

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SMED is short for Swedish Environmental Emissions Data, which is a collaboration between IVL Swedish Environmental Research Institute, SCB Statistics Sweden, SLU Swedish University of Agricultural Sciences, and SMHI Swedish Meteorological and Hydrological Institute. The work co-operation within SMED commenced during 2001 with the long-term aim of acquiring and developing expertise within emission statistics. Through a long-term contract for the Swedish Environmental Protection Agency extending until 2014, SMED is heavily involved in all work related to Sweden's international reporting obligations on emissions to air and water, waste and hazardous substances. A central objective of the SMED collaboration is to develop and operate national emission databases and offer related services to clients such as national, regional and local governmental authorities, air and water quality management districts, as well as industry. For more information visit SMED's website www.smed.se.

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Summary

Sweden reports emissions of fluorinated greenhouse gases (F-gases) annually to the UNFCCC and the EU Monitoring Mechanism. Emissions of F-gases amounted to about 2 per cent of national total emissions 2009 and show an increasing trend since 1990. National and international regulations have entered into force in order to reduce emissions of F-gases. The national system for estimating emission of F-gases is based on national statistics from the Swedish Chemicals Agency and additional information sources. Due to the projected reduction of emissions in the near future, there has been an increasing focus on the reliability of the monitoring of such changes over time, especially for certain sub-categories such as F-gases from mobile air-conditioning equipment.

The aim of this study has been to improve the quality of the collection and emission estimation system in Sweden for F-gases reported to the UNFCCC and the EU Monitoring Mechanism and especially in order to enable better annual follow-up of changes in chemicals flows and emissions of F-gases e.g. due to increased amounts of HFC recovered and the enforced national and international legislations.

The national statistics available and the most important additional information sources and emission factors have been reviewed in this study. The results of this study show that the national statistics from the Swedish Chemicals Agency and the additional information sources continues to be a good foundation for the Swedish emission inventory reporting.

In this study no major adjustments are recommended for the collection and emission estimation system, but there are some suggestions on modifications of emission factors and model macros. In addition, this study includes several recommendations for future improvements on emission inventory quality control checks as well as on national data management procedures.

1 Introduction

1.1 Background

Sweden annually submits greenhouse gas emission inventories to the EU Monitoring mechanism, the UNFCCC and the Kyoto Protocol. The Swedish Ministry of Environment has the overall responsibility and the Swedish Environmental Protection Agency co-ordinates the activities for developing the inventories. The SMED consortium[1] (Swedish Environmental Emissions Data) is contracted to conduct the actual underlying estimations and documentations of the emission inventories. In 2009, greenhouse gas emissions in Sweden amounted to 60 million tonnes CO_2 equivalents (Swedish EPA, 2011). The emissions of fluorinated greenhouse gases (F-gases) Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulfur hexafluoride (SF_6) contributed about 2 per cent (or 1 million tonnes CO_2 equivalents) (Table 1) and they have been increasing steadily since the mid 1990's. Due to the increasing emission trend for F-gases, they are considered to be a prioritised area in the annual national plans for updating and maintaining the greenhouse gas emission inventories in Sweden.

Table 1. Emissions of fluorinated greenhouse gases in Sweden 2009 by CRF source categories, Gg CO_2 equivalents (source: Swedish National Inventory Report/Swedish EPA 2011).

CRF	Source Category	GHG 2009 (CO_2-eq.)
2F1.1-5	Stationary refrigeration	400
2F1.6	Mobile air-conditioning equipment	463
2F2	Foam blowing	40
F3	Fire extinguishers	5.7
F4	Aerosols/Metered dose inhalers	25
F5	Solvents	NE
F6	Other use of ODS substitutes	NO
F7	Semiconductor manufacture	NO
F8	Electrical equipment	45
F9	Other	7.7

NE – Not estimated. NO – Not occuring.

The underlying activity data for estimation of emissions of F-gases are collected annually via the Swedish Chemicals Agency (KemI), Statistics Sweden, information from trade associations and individual companies. The methodology for estimating F-gases in the Swedish greenhouse gas emission inventory is based on three parts of the chemicals life-cycle: emissions from manufacturing, leakage during a products lifetime, and emissions from/at decommissioning. The present model for collection of information on and estimation of emissions from F-gases by Kindbom (2005) and has since been updated annually to reflect changes in Sweden. The last few years, the EU regulation 842/2006, the EU directive 2006/40/EG and the national regulation 2007.846 have entered into force aiming at preventing and minimising of emissions of F-gases. The focus on reliable information on changes in the chemical and product flows and emission estimations of F-gases has thus further increased.

[1] SMED consortium consists of IVL Swedish Environmental Research Institute, Statistics Sweden, Swedish Meteorological and Hydrological Institute and the Swedish University of Agricultural Sciences.

In Sweden, 2009, the single largest sub-category of F-gas emissions stem from the use of air-conditioning systems in motor vehicles (Table 1). The EU directive 2006/40/EG states that from 1 January 2011 member states shall no longer grant EC type-approval or national type-approval for passenger cars fitted with an air-conditioning system designed to contain F-gases with a global warming potential (GWP) higher than 150. In addition, with effect from 1 January 2017, in accordance with the directive, such passenger cars are prohibited to register, sale or enter into service. In the present model for estimating emissions from F-gases in Sweden, all motor vehicles are assumed to be equipped with air-conditioning systems containing HFC-134a (with a GWP of 1300) and no separate annual information collection is performed to verify this assumption. In the latest greenhouse gas projection (Gustafsson and Jerksjö, 2011), emissions of F-gases from mobile air-conditioning equipment are predicted to decline from 463 kton CO_2 equivalents in 2009 to 27 kton CO_2 equivalents in 2030. This calls for a robust information collection and emission estimation system taking such changes into account.

Another area where F-gases are used as refrigerant and where significant market changes have occurred lately are the use of heat pumps, both for institutional and private customers. In Sweden, heat pumps have been introduced as energy-efficient and environmental-friendly alternatives as heating and cooling systems in premises and houses, and the number of installed heat pumps have increased fivefold since 2000 according to the latest statistics from the Swedish Heat Pump Association SVEP (Bertenstam, personal communication). Also for this category of F-gases the underlying assumption of the chemicals used and the emission rate at various stages of the product life-cycle are associated with rather large uncertainties and thus in need of verification.

The use of F-gases as a refrigerant in products was largely introduced in Sweden around 1993-1994. As the product life-time span is around 10-20 years the question of the chemicals flows at decommissioning has only in recent years become an issue. The present model for estimating emissions from F-gases in Sweden does not fully take into account the amounts of F-gases released into the atmosphere at disposal, the amounts recycled, or the amounts exported. During the latest annual national peer reviews of the Swedish greenhouse gas inventory the national experts have made recommendations that information on decommissioning of F-gases in products is needed.

1.2 Objectives

The overall objective of this study is to improve the quality of the collection and emission estimation system for F-gases reported to the UNFCCC and the EU monitoring mechanism and especially in order to enable better annual follow-up of changes in chemicals flows and emissions of F-gases, e.g. due to increased amounts of HFC recovered and the enforced national and international legislations.

1.3 Scope

The study comprises all areas and F-gases reported to the UNFCCC, but products and chemicals covered in the national and international legislations are prioritized. Such areas and chemicals are for example HFCs in mobile air-conditioning, stationary refrigeration, SF_6 in electrical equipment and decommissioning of products containing F-gases.

This study includes a review of the methodology for emission estimations and analyses of possible present and future improvements to the collection and emissions estimation model. The existing model for estimation of emissions of F-gases for reporting to the UNFCCC is handled in MS Excel and consists of numerous interlinked sheets and macro calculations. The model is sufficient for

today's information availability and minor updates and alterations can be performed within this study. Any major changes in calculation matrices due to new information gathered in this study should however be documented and taken into consideration in a subsequent study.

During the national peer reviews of the inventory reporting to the UNFCCC, the national experts made comments about the possibility of existing non-regulatory import of products or decommissioning in Sweden, e.g. disposal of equipment without proper means taken to minimize the emissions of F-gases. That is however outside the scope of this study as such estimates are unreliable and thus highly uncertain.

2 National statistics available

This section describes available national statistics investigated in this study and possible improvements to the use of such sources in the national emission inventory preparation.

2.1 The Swedish Chemicals Agency

The Swedish Chemicals Agency (KemI) is a supervisory authority under the Ministry of the Environment, and works in Sweden and in the EU to promote legislation and rules that contributes to achieving the environmental quality objective of ´A non-toxic environment´ - one of Sweden's 16 environmental quality objectives. In Sweden, KemI supervises importers and manufacturers of chemical products and articles, and supports the supervision of chemicals by municipalities and county administrative boards. KemI's inspectors supervise companies that manufacture and import chemical products and articles. Visits take place throughout the country, and the inspectors check that the legislation is complied with. KemI stores the information in the Products Register.

As part of the Swedish Ordinance (2005:626) Concerning Climate Reporting, KemI is required to compile Products Register data on annual import and export of F-gases in Sweden and submit to SMED. The data is used as basis for the emission estimations for reporting to the UNFCCC, and the completeness, accuracy and consistency of the data is therefore of great importance.

2.1.1 The Products Register

A meeting between SMED and KemI was held within this project to establish the best grounds for deriving available annual information from the Products Register. During the meeting KemI made a short presentation on the Products Register, what rules are applied for notification of products and how to make queries in the database.

The Products Register contains basic facts on nearly 150,000 chemicals and 2,500 businesses. Businesses that annually import, manufacture or changes names of chemical products larger than 100 kg must file a report to the Products Register. Consequently, the register can provide information on status, development and trends in the use of chemicals. An annual chemical charge must be paid for professional manufacture or importing into Sweden for quantities of one tonne or more reported to the Products Register. KemI and other agencies use information in the Register in inspection and enforcement and in various types of preventive activities. In all cases of requested information in the Register a confidentiality evaluation is performed on a case-by-case basis before any information is handed out. Regulations on data confidentiality applicable to the Swedish Chemicals Agency are contained in the Public Access and Secrecy Act (2009:400) and Ordinance (2009:641).

For the requirements of reporting greenhouse gases to the UNFCCC and the EU Monitoring Mechanism, Sweden has a national system to ensure the function of all the institutional, legal and procedural arrangements. Ordinance (2005:626) Concerning Climate Reporting provides the basis for the national system and describes the roles and responsibilities of the government agencies in the context of greenhouse gas emission inventory reporting. Information on chemical products (i.e. where the chemical is the main product) registered in the Products Register is reported to SMED as part of the national system. Chemical products in the Products Register are defined in the Ordinance (2008:245) on Chemical Products and Biotechnical Organisms. According to the ordinance, not all products containing fluorinated gases are included in the Register, e.g. air-condition equipment in imported vehicles and in heat pumps and thus not reported to SMED as part of the national system.

Data reported by companies to the Products Register are checked in order to avoid that significant amount of chemicals are missing or that a company has reported chemicals using the incorrect unit (e.g. kg instead of ton). Imported products that are distributed and sold to other companies in Sweden do not have to be notified again in the Products Register. Only if the products name is changed another notification is needed. KemI keeps track of products changing names in order to avoid double counting of chemicals. During the meeting KemI explained that exported chemicals do not include recovered volumes e.g. for recycling or incineration abroad. Recovered chemicals are not part of the Products Register at all.

In Table 2 it can be seen that imported HFCs 2005-2009 in Sweden according to the Products Register annually amounts to about 0.8-1 kton HFCs. Imported PFCs are not presented due to confidentiality, but are likely to be less than 2 tonnes annually. There is no information on exported PFCs or SF_6 in the Products Register 2005-2009.

Table 2. Import and export of fluorinated greenhouse gases in Sweden 2005-2009 (source: the Swedish Chemicals Agency's Products Register)

Year	Import (ton)			Export (ton)		
	HFCs	PFCs	SF_6	HFCs	PFCs	SF_6
2005	899	C	54	54	0	0
2006	961	C	58	21	0	0
2007	952	C	67	25	0	0
2008	1019	C	70	24	0	0
2009	833	0	56	23	0	0

C – Confidential.
Data for 2010 is not available until 2012, in preparation for the 2013 submission.

As chemical products of less than 100 kg are not always included in the Register, SMED raised the concerns of a possible bias in volumes which might lead to underestimations of emissions from F-gases. KemI predicted that such volumes are insignificant and within the uncertainty confidence intervals. Hence, there is no evidence that adding extra volumes would lead to reduction of the uncertainties.

In this study KemI granted IVL access to confidential data on imported and exported amounts of F-gases by company 2009. The data has been handled by IVL in accordance with the Swedish regulations on data confidentiality (2009:400 and 2009:641). Company-specific data have been grouped and used to compare the chemicals allocated on different sub-sectors in the present calculation model. KemI data and model data show good coherence for all chemicals and sub-categories. For HFC-134a there is however difficulties in fully making relevant data comparisons since some of the companies reporting to KemI in turn distribute the chemicals to various sub-categories and information on sub-category splits are not included in the KemI data.

Despite the fact that KemI data does not include all chemicals imported to or exported from Sweden, the annual statistical output is judged to be the best foundation presently available in Sweden for emission inventory reporting of F-gases. The data usefulness would be further improved if KemI was to include in the Products Register also information on e.g. F-gases in air-condition equipment in imported vehicles and heat pumps.

2.2 The Swedish Environmental Protection Agency

The Swedish Environmental Protection Agency (Swedish EPA) is the public agency in Sweden that has an overview of conditions in the environment and progress in environmental policy as well as responsibility of coordinating, monitoring and evaluating efforts, involving many agencies, to meet Sweden's environmental objectives.

The Swedish EPA is responsible for the reporting of F-gases to the European Commission (EC). According to EC 842/2006 owners of refrigeration, air-conditioning, heat pump and fire extinguisher equipment containing 3 kg or more F-gases must maintain records. In addition, installation, maintenance and service of F-gas-containing equipment must only be handled by authorised personnel. In Sweden, Municipal or County Administration Boards are responsible for supervising the records. The Swedish EPA collects information from these records for reporting to the EC. The reporting is however not complete and is thus not at present useful for the greenhouse gas national emissions inventory system. The Swedish EPA would like to improve the existing collection system to enable useful data collection for this purpose (Ujfalusi, personal communication).

F-gases are considered hazardous wastes and a permit is needed for import or exporting such wastes. The Swedish EPA is responsible for handling permissions for transporting of hazardous waste to and from Sweden. In this study it was investigated if such data could be used for the purpose of estimating imported or exported used F-gases. However, the data does not contain any references to F-gases. It is possible that some amounts of F-gases are covered by e.g. electrical equipment, but most likely it accounts for insignificant amounts and can be ignored. This information suggests that no F-gases are exported as hazardous wastes. Knowing that e.g. AGA send some of their recovered gases abroad for final treatment suggests that recovered amounts of F-gases is not always considered to be hazardous wastes.

In this study it has been judged that the different information sources available at the Swedish EPA could not be used to improve the quality of the present system for emission reporting to the UNFCCC and EU Monitoring Mechanism.

2.3 The Swedish Customs and Statistics Sweden

Fluorinated greenhouse gases are imported to and exported from Sweden through various businesses. Companies are obliged to report such border activities to the Swedish Customs. Information on import and export statistics is publically available via Statistics Sweden's Statistical database. Import and export of F-gases in Sweden are found in three types of the Combined Nomenclature[2] (CN), i.e. CN38247100, CN38247400 and CN38247800 (Table 3). CN38247100 and CN38247400 mainly contain CFCs and HCFCs, respectively, but may also contain some HFCs and PFCs. CN38247800 contains only HFCs and PFCs. Statistics on import or export of SF_6 cannot be found in the database.

[2] The Combined Nomenclature is the result of the merger between the Common Customs Tariff nomenclature and Nimexe (EU Statistical Nomenclature)

Table 3. Import and export of fluorinated greenhouse gases in Sweden 2005-2009 (source: Statistics Sweden's Statistical database)

Year	Import (ton)			Export (ton)		
	CN38247100	CN38247400	CN38247800	CN38247100	CN38247400	CN38247800
2005	0	0	0	133	0	0
2006	10	0	0	17	0	0
2007	35	4	89	5	1	16
2008	31	7	238	0	4	120
2009	0	1	321	0	75	82
2010	0	37	584	0	58	205

CN38247100 - Contains CFCs, but also HCFCs, PFCs and HFCs. CN38247400 - Contains HCFCs, but also PFCs and HFCs. CN38247800 - Contains PFCs and HFCs.

Compared to import and export statistics from the Swedish Chemicals Agency (Table 2), it can be seen in Table 3 that imported amounts of HFCs and PFCs (CN38247800) via Statistics Sweden are significantly less. This indicates that not all imported HFCs and PFCs are registered in the Statistical database. That makes the database presently less useful for comparison of information with the data from the Swedish Chemicals Agency. Statistics on exported amounts of HFCs and PFCs (CN38247800) show large variations 2007-2009 (for 2005-2006, no statistics is available). Compared to the information on exported HFCs from the Swedish Chemicals Agency (Table 2), the data from Statistics Sweden indicate that significantly more HFCs are exported 2008-2009. One possible explanation for the large number of exported HFCs and PFCs from Statistics Sweden could be that the data contains recovered volumes sent abroad for recycling or destruction. Due to confidentiality in data from Statistics Sweden, it has not been possible in this study to investigate the underlying reasons for the large discrepancies between the two data sources. KemI has suggested that a collaboration project between KemI and the Swedish Customs could shed some light on the differences in data.

3 Source-specific emission inventory information needed

This section describes what source-specific information has been reviewed in this study and suggests changes to the present data collection system and emission calculation model due to new information acquired.

3.1 Air-conditioning in vehicles

Several sources have been contacted in this study to acquire information on fluorinated greenhouse gases in air-conditioning equipment in Sweden;

- Dehon, one of Europe's specialists in cooling fluids for refrigeration and air conditioning.
- Dometic Scanidinavia AB, supplies and service the industry and after market with air conditioners, refrigerators, etc.
- Refnet, one of the largest distributors of HFC for air-conditioning equipment in vehicles in Sweden.
- Scania, a leading manufacturer of heavy trucks, buses and coaches.
- Volvo Cars, the largest passenger car manufacturer in Sweden
- Volvo Trucks, one of the world's largest truck manufacturers.

3.1.1 Passenger cars

According to Volvo Cars (Andersson, personal communication) and Dehon (Nilsson, personal communication), within the EU, HFO-1234yf (2,3,3,3-Tetrafluoropropene with a GWP of 4) as refrigerant in air-conditioning in passenger cars is under development and thought of as an alternative to using HFC 134a. The introduction of alternative refrigerants in mobile air-conditioning has been delayed, and in the Swedish market, HFO-1234yf will likely be introduced in passenger cars in mid-2011 or beginning of 2012 according to Dehon. In the meantime, Volvo is considering using HFC-152a (GWP=140) as an alternative to HFC-134a (GWP=1300). The Swedish Chemicals Agency will include HFO-1234yf in its annual deliverables to SMED from reference year 2010. The information from Volvo Cars and Dehon on that HFC-152a or HFO-1234yf will be introduced in mid-2011 or beginning of 2012 does not result in any changes of historical emission data. HFO-1234yf is not part of the present UNFCCC regulation and the reporting guidelines for the next commitment period are not yet adapted by the Convention. Hence it is presently not decided if HFO-1234yf will be included in future emission inventory submission to the UNFCCC and EU Monitoring Mechanism.

According to Volvo Cars, some of the EU car manufactures are considering using CO_2 as alternative in air-conditioners. CO_2 as refrigerant in air-conditioners require larger, heavier and higher pressure systems than HFC-134a and thus only considered an alternative for heavy passenger cars or heavy-duty vehicles and busses. In this study, the Swedish manufactures of heavy-duty vehicles and busses have not made any comments on possible implementation on CO_2 as refrigerant.

In this study the MS Excel macros used in the calculation model have been scrutinized and errors in the programming were detected related to the "accumulated_minus_leakage" and the "leakage_per_year" macros. The errors refer to the use of the "Annual leakage" factor which is fixed on the 1990 value instead of varying with emission year. It is suggested that these errors are corrected in a subsequent study. In addition, several factors for air-conditioning equipment in vehicles (MAC)

are suggested to be revised due to new or updated information from manufacturers and other companies (Table 4).

In IPCC 1996 Guidelines the average charge per AC in passenger cars is 0.8 kg. In Sweden it has been suggested by Volvo Cars (Andersson, personal communication) and Dometic Scandinavia AB (Johansson, personal communication) that from 2011, the average charge is more likely around 0.7 kg. Due to the introduction of smaller passenger cars in Sweden in recent year, it is likely that the average charge will continue to decrease and information on the progress should thus intermittently be followed up. According to Volvo Cars leakage of HFC-134a at manufacturing of MACs derives at less than 1 g per MAC, which equals about 0.15% leakage rate. Due to the uncertainty in the measurements, it is suggested that the factor for leakage at initial charge of MAC (e.g. at production) is reduced from 1% to 0.5% from 2011 (which is the default value in IPCC Good Practice Guidance). The previous figure was provided by Volvo in 2003.

In the present calculation model, annual leakage during the equipment lifetime for MAC in passenger cars is assumed to be 15% in 1990 and 10% since 2001. According to Volvo Cars and Dometic Scandinavia AB the range of annual leakage is about 7-20 g. This equals about 1-3% of annual leakage. Based on information from Volvo Cars and Dometic Scandinavia AB in this study it is suggested that the factor in Sweden is reduced to 7.5% in 2010 and to 5% 2011 onwards. Furthermore, the present factors for annual leakage (operation emissions) refer to leakage from equipment at normal conditions (including leakage at service) and do not include leakage at minor accidents causing the MAC to erupt and fully release the refrigerant. It is suggested that annual leakage from operation emissions and accidental emissions are combined. In the present model, it is assumed that 90% of the HFC-134a in MAC remains at the equipment disposal, which is considered to be a high proportion. No information has been available in this study to revise that figure so it is suggested that the default value (40%) from the IPCC Good Practice Guidance is applied. The recovery efficiency rate at disposal (end-of -life emissions) is kept at 85% (i.e. an emission rate of 15% at disposal).

Table 4. Suggested revision of model factors for mobile air-conditioning.

Sector	Factor	Present value	Revised value	Reference to new value	Approx. effect on GHG/year (CO_2-eq.)
AC passenger cars	Charge per AC	0.8 kg	0.7 kg from 2011	Volvo, Dometic Scandinavia AB	3
All mobile AC	Leakage at initial charge	1%	0.5% 2011 onwards	IPCC 1996, Volvo	2
AC passenger cars	Annual leakage, operation emissions	10% since 2001	7.5% 2010. 5% 2011 onwards	Volvo, Dometic Scandinavia AB	-10
All mobile AC	Annual leakage, accidental emissions*	NA	5% 1990 onwards	Dometic Scandinavia AB	12
All mobile AC	Residual charge at disposal	90%	40%	IPCC Good Practice Guidance	-12

*Refers to leakage due to minor accidents causing air-conditioner eruption, but not car wreckage.

The information from the confidential company-specific data provided by the KemI show good coherence with model data on sub-sectors except for HFC-134a, for which it has been difficult to fully make reliable data comparisons. In the present allocation model there is no amount of HFC-134a estimated for refilling during service of MAC, only for refrigerants in imported vehicles and vehicles

manufactured in Sweden. It is therefore suggested that the calculation model is improved by reallocating HFC-134a from other stationary refrigeration to MAC using information on estimated amounts for refilling of HFC-134a at vehicle services. Amounts of HFC-134a for MAC service should be calculated as a proportion of annual leakage of HFC-134a the previous year.

Based on the information from Refnet (Berg, personal communication), HFC-134a in non-refill containers are not used since 2006 in Sweden. This calls for revision of emissions estimates. A revision of data would lead to that about 88 tonnes HFC-134a 2007-2009 are reallocated from MAC to other stationary refrigeration equipment.

3.1.2 Heavy duty vehicles and busses

Scania and Volvo Trucks have been contacted to verify the different factors used in the national model for calculating emissions of F-gases. However, no additional information has been obtained to suggest that any changes should be made.

3.2 Stationary refrigeration

In this study, some of the emission model assumptions (e.g. lifetime expectancy, emissions at manufacturing, installed amount of liquid per unit, etc.) were discussed with the refrigeration trade association Kylimportörerna to make possible verifications. There are however no data available to either support nor change the assumptions, but in the model context, the assumptions were deemed to be reasonable.

3.3 Heat pumps

In the present system for estimating GHG from heat pumps it is incorrectly assumed that all F-gases are imported together with the pumps, already installed and that such volumes of F-gases are not included in the annual statistics from KemI. During communication with the Swedish Heat Pumps Association SVEP (Bertenstam, personal communication) it has been clarified that only air-to-air heat pumps largely are imported prefilled with the refrigerant R-410A (mixture 50% HFC-125 and 50% HFC-32). That equals about 50% of the total installed amounts of F-gases in heat pumps in 2010. It is therefore suggested that the amount of HFCs used for filling of heat pumps in Sweden should be accounted for in the calculation model when balancing the national total volumes provided by KemI. Correcting these volumes will lead to lower amounts of HFCs (about 76 tonnes 2009) allocated to the other stationary refrigeration (as the current methodology applies).

3.4 SF_6 in electrical equipment

ABB is a global leader in power and automation technologies and the largest user of SF_6 in Sweden. SF_6 is used as a switching and insulation medium in electrical power equipment (gas-insulated switchgears) because of its unique physical properties. Each year ABB provides SMED with information on SF_6 in terms of import, export, emissions, use of and amounts sent for destruction. The data from ABB is in good comparison with statistics from Swedish Chemicals Agency. Information from ABB (Settervall, personal communication) reveals that SF_6 used for manufacturing of electrical equipment includes SF_6 held as stock and thus should be used for estimation of annual emissions. Previously in the calculation model, information on imported SF_6 has been used for this purpose. It is recommended that information on SF_6 used for manufacturing instead of imported SF_6 is applied in the calculation model to estimate emissions of SF_6. This will however only lead to minor corrections of emission data.

3.5 Recovery and disposal

According to the refrigeration trade association Kylimportörerna (Björn, personal communication) and one of the largest companies for recovery of F-gases in Sweden (Jessen Jürgenssen AB, personal communication), about 10% of the imported amounts of HFCs annually are recovered for destruction in Sweden or for export. Applying this assumption on the Swedish inventory, about 80-100 tonnes HFCs should be subtracted from the model each year. Due to confidentiality in data, the sources are not able to provide information on how much of the recovered amounts of HFCs are exported and destructed in Sweden, respectively. However, according to Jesse Jürgenssen AB most of the recovered HFCs in Sweden are sent for destruction. In order to destroy F-gases by incineration in Sweden, a special permit is needed. The permit also includes destruction of HCFC. In Sweden, only a few facilities have such permit. SAKAB, the largest facility for incineration of hazardous wastes in Sweden, has been contacted in order to verify the information on annual disposal of HFCs. Due to technical problems with their waste management information system, SAKAB (Melander, personal communication) was however not able verify the information. In the present model about 6-15% of the yearly inflow of HFCs is removed from the model via emissions and destruction of HFCs. It is recommended that the model is adjusted to account for about 10% annual recovery of HFCs.

According to Kylimportörerna and SAKAB, emissions from leakage at recovery or destruction of HFCs are insignificant.

4 Discussion and conclusion

The information analysed in this study indicate that the present system for data collection and emission calculation gives good approximation of national fluorinated greenhouse gas (F-gas) emissions in Sweden for reporting to the UNFCCC and the EU Monitoring Mechanism. However, for annual follow-up of international and national legislations the system lack some of the detailed information needed. In order to enable better achieved such information, it is suggested that the Swedish EPA investigate if the National system in the next commitment period should be expanded, e.g. to include also F-gases presently not registered in KemI:s Products Register. Moreover, a better foundation for the Swedish EPA data collection system for amounts of refilling of F-gases reported by the Municipal or County Administration Boards could give additional strength to the F-gas emission monitoring.

Additional company-specific import data on F-gases provided by KemI did not give enough information to enable precise follow-up of the EU directive on F-gases in passenger cars. This is due to the fact that not all car manufacturers and importers of cars are represented in the statistics. Data is based on companies importing the chemicals and they are not always the same as the users. KemI has agreed to start including HFO-1234yf in the annual statistics to SMED. Hence, if the chemical is introduced as alternative to HFC-134a as refrigerant in passenger car air-conditioning equipment, KemI statistics will give a good approximation of the expected decline in the use of HFC-134a that sub-sector and thus enables Sweden to follow-up the EU directive 2006/40/EG.

It is evident that the annual statistical output from KemI continues to be a good basis for F-gas emission estimates in Sweden. It is however, of utmost importance that the amounts of F-gases not included in the Products Register are closely monitored and carefully estimated, e.g. air-condition equipment in imported vehicles or heat pumps.

The results from this study suggest that no major input or model adjustments are needed. There are however several recommendations on data and model factor updates as well as correction of macros presented in this study. Some are recommended to be implemented in the 2012 submission to the UNFCCC and EU Monitoring Mechanism (section 4.1), and some are given as recommendations for future improvements (section 4.2). In this study, there are no estimated figures on the implication of suggested future improvements.

Information on emissions from F-gases in Sweden is associated with relatively large uncertainties. It has been judged that the present uncertainties estimates are valid also after this study.

4.1 Recommended revisions for the 2012 submission to the UNFCCC and EU Monitoring Mechanism

In this study changes to the data input and calculation model are recommended that could be implemented in the 2012 submission to the UNFCCC and EU Monitoring Mechanism without additional means:

- Revision of model factors for mobile air-conditioning equipment as presented in Table 4.
- Information from SVEP on HFCs used for filling of heat pumps in Sweden should be accounted for in the model and not regarded as imported HFCs in goods.
- Revise information on HFC-134a in non-refill containers 2007-2009.
- Adjust model calculations for SF_6 in electrical equipment so that SF_6 used for manufacturing instead of imported SF_6 is applied.

4.2 Recommendations for future improvements related to the emission inventory

It is recommended that the Swedish EPA in preparation for the 2013 submission to the UNFCCC and EU Monitoring Mechanism initiates a follow-up study including the following suggested improvements:

- Correction of erroneous excel macros "accumulated_minus_leakage" and "leakage_per_year".
- Balance model output on recovered HFCs with the information from the trade association.

Furthermore it is suggested that the following future activities are carried out:

- Annual application by SMED to KemI to gain access to all aggregated national data including confidential information.
- Assumptions on model factors should be checked with the trade associations and manufactures every five years. This especially applies to factors for passenger cars, heavy duty vehicles and busses, but also stationary refrigeration equipment.
- Annual company-specific data from KemI should be checked every 4-5 years with data collected by SMED in order to ensure that the model assumptions are still adequate.
- The present Swedish projections on F-gas emissions include assumptions that HFC-152a as the alternative to HFC-134a in passenger car air-conditioning equipment. It is suggested that future projection projects take into account the expected progress on other alternatives, such as HFO-1234yf.

4.3 Possible future improvements on national data availability

The recommendations described above (4.1 and 4.2) are within the scope of the present National system for emission inventory reporting to the UNFCCC and the EU Monitoring Mechanism. In this study, several additional possible future improvements are discussed below:

- The national data on imported and exported chemicals provided by KemI is incomplete in terms of total national input and output of F-gases. An extension of the KemI mandate to include all chemicals regardless of purpose would enable improved data quality of the emission inventory.

- Furthermore, national statistics provided by Statistics Sweden based on information from the Swedish Customs are presently not comparable with the KemI data. A collaboration project between KemI and the Swedish Customs could help identify the reasons for the large differences in data.
- The Swedish EPA holds a register on annual amounts of F-gases used for service and maintenance as well as a register for import and export of hazardous wastes. The registers are presently not suitable for extraction of information useful for the emission inventory reporting. It is therefore suggested that the Swedish EPA in cooperation with SMED identify possible future improvements.

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