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Finnish 2001 inventory of HFC, PFC and SF₆ emission

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SUMMARY

Finnish emissions of HFCs, PFCs and SF₆ amounted to 0.7 million metric tons of carbon dioxide equivalent in 2001. A 95% certainty range for this estimate is 0.4...0.8 Mt CO₂-eq. Potential emissions were approximately two-fold totaling 1.3 Mt CO₂-eq. Emissions of F-gases thus contributed 0.9% of the total greenhouse gas emissions in 2001.

Emissions increased by 27% from previous year, and were eight-fold compared to year 1990 emissions. Most of the growth in emissions occurred due to the increased use of HFCs and PFCs as refrigerants and propellants, in which use they have substituted most of the previous use of ozone depleting CFCs and HCFCs.

Majority of the F-gas emissions in 2001 (75%) originated from refrigeration and air conditioning. Emissions from aerosols, one-component polyurethane foam cans, foam blowing and electrical equipment contributed 22% of the emissions. An aggregated estimate for confidential emissions data—magnesium die-casting, running shoes, fixed fire fighting equipment, HFC-23 from refrigeration and air conditioning, and semiconductor manufacturing—amounted to some 3% of total F-gas emissions.

The F-gases inventory was improved by quantification of uncertainties. Most of the uncertainty results from under-coverage of the survey of refrigeration and air conditioning industry. Means to reduce this uncertainty was identified and improved confidence in the estimates is expected for the next inventory. The inventory was also improved by addition of a new source, implementation of better calculation models and data, as well as inclusion of recommendations made by expert review teams during the reviews of the Finnish inventory.

1 INTRODUCTION

This report documents the Finnish 2001 inventory of HFC, PFC and SF₆ (F-gases) emissions. The results of the inventory were reported as a part of Finland's annual greenhouse gas inventory submission. The submission, consisting of Common Reporting Format (CRF) tables and a National Inventory Report (NIR), were sent to European Commission in December 2002 and in April 2003¹, and to the Secretariat of the United Nations Framework Convention on Climate Change (UNFCCC) in April 2003.

The submission of information to Commission takes place under the Monitoring Mechanism on Greenhouse Gas Emissions (Council Decision 1999/296/EC). The commission then prepares an inventory for the European Community, and submits this inventory to the UNFCCC Secretariat. The obligation to submit information is laid down in the Treaty itself. As a Party to UNFCCC Finland also delivers its own separate inventory to the Treaty.

The main aim of this document is to provide a more detailed description of the inventory fundamentals (data, methods) than what was possible to include in the NIR. It describes the methodologies used to calculate emissions, how data for these calculations were gathered and how uncertainties were quantified. It also explains actions taken to ensure that everything has been calculated and reported correctly, and answers to questions identified during reviews of past inventories. Recalculations carried out and reasons for these are also documented. Emission estimates (potential as well as actual) are presented for each of the sources using the categories of the CRF. The report ends with conclusions and recommendations for future work.

Appendix 1 of this document provides links between the CRF tables and sections of this report. The purpose of the table is to assist reviewers of the inventory² in finding background information on the numbers reported in CRF.

¹ December and April submissions were not identical: activity data was revised in between the two submissions, leading to a higher emission estimate in April's submission.

² Review of greenhouse gas inventories submitted to UNFCCC is a process, which aims to ensure that the Conference of the Parties have reliable information on emissions.

2 METHODS

2.1 Overview of the approach

The method used to produce the inventory of Finnish emissions of F-gases is based on the use of company surveys. Data needed to produce the estimates are gathered using survey forms sent out to companies via postal or electronic mail. Companies are contacted several times in order to achieve sufficient response activity, i.e. to get as many responses as possible, and to make sure that responses from important actors in the sector are not missing. The data-gathering phase of the process is described in section 2.5 (p. 15).

Forms filled in by companies are checked for consistency of information at arrival. The delivery of responses is also monitored to enable further contacts with non-responding companies (for instance, Figure 2.5-2 on p. 17 displays the effect of reminding companies three times after first contact).

After completion of the data-gathering phase, responses are saved into a database, from which data can be retrieved for further analysis. The aim is to have reliable data for input to emission calculation models, which are described in section 2.4 below (a summary of the models used is given in Table 2.4-5 on p. 14).

Inventories should aim for transparency, accuracy, consistency, completeness and comparability. These terms have specific meanings within the UNFCCC inventory framework (paragraph 4 of FCCC/CP/1999/7).

Completeness and transparency can be assessed on the basis of information presented in section 2.2 below. When it comes to transparency, protection of data sources should be considered, as is explained in section 2.7 (p. 18). Sections under 2.4 are hoped to facilitate the review of consistency and comparability. Means to improve accuracy through quantification of sources of uncertainty are explained in section 2.3.

2.2 Sources included in and excluded from the inventory

Historically, the level of emissions of F-gases has been very low in Finland. This is explained by the absence of certain large industrial point sources that account for most of the emissions globally. First of all, F-gases are not produced in Finland. This means that there are no emissions from manufacturing. Moreover, there is no manufacturing of other fluorinated gases, such as HCFCs that could lead to by-product emissions (e.g. HFC-23 from HCFC-22 manufacturing). Other point sources that have generated a considerable amount of emissions elsewhere, but are absent in Finland, include primary aluminum and magnesium industry.

F-gases emissions from Finnish sources thus follow from consumption of these gases in various applications. These consumption-related sources included in this inventory are:

- SF₆ used as a cover gas in magnesium die-casting
- SF₆ used in electrical equipment (gas insulated switchgear and circuit breakers)
- SF₆ used in "adiabatic property applications" (sport shoes)
- HFCs, PFCs and SF₆ used in semiconductor manufacturing
- HFCs and PFCs used as refrigerants in refrigeration and air conditioning equipment (including heat pumps)
- HFCs used as propellants in aerosols and one-component polyurethane foam
- HFCs used as blowing agents in manufacturing of various kinds of polyurethane, extruded polystyrene and other foam products

- HFCs used as extinguishing agents in fixed fire fighting systems.

The use of HFCs as solvents is documented in the literature, but so far there has been no indication of such use in Finland.

In the inventory, the "adiabatic property" or "semi-prompt applications" of SF₆ consist of SF₆ emitted from shoes. The contribution of other "semi-prompt" applications, such as double glazed windows, to Finnish emissions of SF₆ was considered negligible and these sources were not included in the inventory (section 2.4.3 p. 9).

In reporting the results—both in the CRF tables and the tables of this report—, HFC-23 from refrigeration and air conditioning, HFCs used as extinguishing agents, SF₆ from shoes, SF₆ from magnesium die-casting as well as HFCs, PFCs and SF₆ used in semiconductor manufacturing have been aggregated into one source category called "grouped data". This was necessary to ensure that breaches of confidentiality are avoided (section 2.7 p. 18). Confidential figures are marked with "C" throughout this report.

2.3 Uncertainty analysis

The main purpose of quantifying uncertainty was to get an idea on how much confidence could be placed on the estimates. Uncertainty analysis is also useful in pointing out the things that could be improved, if more accurate estimates are required.

Uncertainties in estimates, resulting from uncertainties in activity data and emission factors, were quantified using Monte Carlo simulation. Models to calculate emission estimates were implemented as MS Excel spreadsheets and simulations were carried out with Crystal Ball add-in to MS Excel. Uncertainties in both the 2001 level of emissions, and the trend of emissions (change between 1990 and 2001), were quantified for each of the sources. Similarly, the trend uncertainty was quantified for overall emissions of F-gases.

Good Practice Guidance was followed in selecting probability density functions for input parameters (Galbally et al. 2000 pp. A1.8–A1.9). Selected distributions are documented for each of the sources in the following sections of 2.4 Choice of emission models.

Empirical data have been used to the extent possible in selecting probability density functions. There are parameters, however, that lack such data. In many cases activity data come from companies' bookkeeping with no indication of associated uncertainty. In such cases it has been assumed that the data is fairly certain and associated with an uncertainty of ±5% (normally distributed around the mean).

2.4 Choice of emission models

2.4.1 SF₆ emissions from magnesium die casting

SF₆ is used as a cover gas in magnesium industry. The industry can be further divided into the following segments:

- Primary magnesium production
- Die-casting
- Gravity casting
- Reprocessing (secondary production).

The current understanding is that only die-casting is present in Finland, and that one company is engaged in die-casting activity (Lemmetti 2002). The company produces magnesium components for telecommunication products (mainly mobile

phones). The data available for emissions reporting (as provided by the company) covers the whole history of SF₆ use at the facility from 1994 to 2002.

Emissions from this source are calculated using the "direct reporting method", which is a model that equates SF₆ emissions with gas consumption (Palmer 2000). The quantities of SF₆ that were imported for this purpose were included in the Tier 1a potential emission estimate (Anon. 1997 pp. 2.47–2.50). Uncertainty in the consumption figure for 2001 was assumed as ±5% and normally distributed.

2.4.2 SF₆ emissions from electrical equipment

SF₆ is also used as an electrical insulation medium and arc-quenching agent in gas insulated switchgear and circuit breakers, from which it may leak to the atmosphere. The model that was used previously to calculate these emissions relied on the use of emissions factors for manufacturing and installation, use, and disposal of electrical equipment. National emission factors based on actual measurements have not been available, so the values used for these factors were based on expert judgment. The use of the model also involved contacting a large number of electrical equipment users (approximately 100) in order to obtain the necessary information. The emission factor based model is described in Anon. (1997) and was used for inventory years from 1990 to 2000 (Oinonen 2000).

However, as the level of emissions from electrical equipment have proved to be low compared to overall emissions in Finland, it was decided that it would be preferable to use a model that is less data-intensive. The Good Practice Guidance, published in September 2000 (Penman 2000), described three new methods (Tier 3a, 3b and 3c) for electrical equipment. The Tier 3c method (country-level mass-balance method) has the advantage that it does not depend on the use of emission factors. It is also possible to obtain the activity data from manufacturers and importers of electrical equipment, the number of which is far smaller compared to that of equipment users.

The disadvantage of the model is that it also relies on assumptions regarding a number of input parameters that may be associated with high uncertainty. Changing models would also entail an update of the previous inventories of the source. Nevertheless, as advantages seemed to outweigh disadvantages, a decision to change from bottom-up model to country-level mass-balance model was made. According to this model, SF₆ emissions from electrical equipment are calculated as follows:

$$E = S - C - D$$

where *S* is annual sales of SF₆ to electrical equipment manufacturers, users, service companies, and contractors (including SF₆ imported in equipment and excluding SF₆ exported in equipment). *C* is the net increase in total nameplate capacity, which is calculated by subtracting the sum of nameplate capacities of retiring equipment from the sum of nameplate capacities of new equipment. Here, the concept of nameplate capacity, or "charge", refers to the amount of SF₆ required to fill a piece of equipment so that it will function properly. *D* is the amount of SF₆ destroyed each year—obviously, this must be gas used in and recovered from electrical equipment. In other words, all sold quantities of SF₆ that do not increase the total nameplate capacity, are counted as emissions (recovered and destructed quantities are not counted as emissions).

In the chosen model (Olivier & Bakker 2000 pp. 3.59–3.60), the retiring nameplate capacity is calculated, based on an assumed equipment lifetime and an annual estimated growth rate of equipment capacity, which was obtained through a survey of Finnish utilities. The nameplate capacity of new equipment is also needed, and this is obtained through a survey of Finnish importers and manufacturers. The relationship between retiring nameplate capacity and the new nameplate capacity is thus given by

$$RC = \frac{1}{(1+g)^L} NC$$

where NC is the new nameplate capacity, g is the capacity growth rate, and L is the assumed lifetime of electrical equipment. Data for installed quantities during 1978–1998 was used to estimate g . There is considerable variation in annually installed quantities during that period. Because of difficulties in fitting a probability density function to the data, a median of 7% was chosen as the likeliest value to describe typical annual growth. Based on the 2.5 and 97.5 percentiles, 0 and 91% were chosen for minimum and maximum values of growth. A triangular probability density function with these values was then used in simulations. For equipment lifetime, a normal distribution with a mean of 30 years and a standard deviation of 7 years was chosen. Uncertainty associated with new nameplate capacity and annual sales were estimated as $\pm 5\%$ and normally distributed.

Potential emissions were calculated according to Tier 1b model (Anon. 1997 p. 2.48) using survey and emissions data.

2.4.3 SF₆ emissions from other sources

In addition to magnesium die-casting and electrical equipment, there are a variety of other potential emission sources of SF₆. These include gas-air tracer use in research, leak detectors, medical purposes, equipment used in accelerators, lasers and night vision goggles, military applications, sound-proof windows and applications utilizing the adiabatic property of the gas (e.g. car tires, sport shoes, tennis balls) (Olivier & Bakker 2000 p. 3.63).

Annual surveys of specialty gas importers in Finland suggest that very little if any SF₆ is being used as a tracer and in medical purposes, or any other uses that require bulk SF₆ consumption. Moreover, SF₆ containing car tires are considered a German specialty, and it is assumed that cars imported to Finland do not contain SF₆.

SF₆ has been used, however, to produce soundproof windows in Finland. The production started in mid-1980s and by 2000 some 15 000 m² of windows had been produced. There are no annual statistics of gas consumption available for this use, but it has been estimated based on the quantity of windows manufactured, years of production, and assumed losses from manufacturing of 30–60%, that by 2000 the quantity used had been less than 600 kg, or an average of 40 kg per year. It also seems that this use is gradually being phased out. (Oinonen & Soimakallio 2001) Thus, the low gas consumption, lack of data to reproduce annual variations in consumption, and the phasing out of the use, have lead to a decision not to include this source in the inventory.

SF₆ in shoes on the other hand are included as a new source in the inventory. Emissions from this source were estimated for 1990–2001 period using a model for adiabatic property applications (Olivier & Bakker 2000 p. 3.65). This model equates emissions in year t with sales in year $t-3$. Thus, annual shoe sales statistics, the proportion of shoe sales containing SF₆, as well as an average shoe SF₆ content are required to perform this calculation. It has been agreed with the importing company not to document these figures because of confidentiality; moreover, it has been agreed with the company that emissions are reported in the aggregated "grouped data" category. Tier 1b model was used to calculate potential emissions (Anon. 1997 pp. 2.47–2.50).

2.4.4 HFC, PFC and SF₆ emissions from semiconductor manufacturing

The first survey of F-gas users in the semiconductor industry was carried out in 1999 through Federation of Finnish Electrical and Electronics Industry. Results from this

survey cited figures for two years in 1990s. This information was used together with previous estimates for 1990 (which we carried out by another institute). Interpolation was then used to arrive at estimates for emissions in 1990–1998 period. Also, specialty gas importers were surveyed for 1999 and 2000 sales of HFCs, PFCs and SF₆ to semiconductor industry. Surveys of both suppliers and users indicated very low F-gas consumption within the industry. Due to the low quantities consumed, and the negligible contribution of this source to Finnish greenhouse gas emissions, the use of sophisticated models could not be justified given the time and resources. Therefore, consumption figures have previously been reported as emissions.

However, in 2002 a direct survey of gas users (companies, universities, research institutions) in the Finnish semiconductor industry was carried out for the first time. The aim was to make use of the model described in the Good Practice Guidance, and to make sure that previous data from importers reflect the actual consumption within the industry.

Based on users' reported quantities for consumption, Tier 1 model was used in calculating emissions (Bartos & Burton 2000 p. 3.72). Tier 1a model was also used to calculate potential emissions for the source (Anon. 1997 pp. 2.47–2.50). Note that the application of Tier 1b model to this category is not meaningful—or the calculation is simply reduced to Tier 1a—because all imports of gases used in manufacturing take place in bulk quantities. Moreover, the gas is not contained within the manufactured products in a form that could be later released to the atmosphere.

Table 2.4-1 shows the probability density functions used in simulations. The means are default values reported in the Good Practice Guidance (Bartos & Burton 2000 p. 3.74). The standard deviations are assumptions, not based on experience or empirical evidence. Other values used in simulation cannot be tabulated due to the small number of semiconductor manufacturers in Finland.

Table 2.4-1: Probability density functions (PDFs) used in simulating emissions from semiconductor manufacturing. Note that parameter values for activity data cannot be tabulated due to confidentiality. N = normal distribution, mean (m) and standard distribution (s) are given in parenthesis N(m,s).

Parameter	PDFs used in simulation				
	CF ₄	C ₂ F ₆	CHF ₃	C ₃ F ₈	SF ₆
Fraction of gas remaining in container after use	N(0.1,0.1)	N(0.1,0.1)	N(0.1,0.1)	N(0.1,0.1)	N(0.1,0.1)
Fraction of gas transformed or destroyed in process	N(0.2,0.1)	N(0.3,0.1)	N(0.7,0.1)	N(0.6,0.1)	N(0.5,0.1)
Emission factor (kg CF ₄ / kg gas)	-	N(0.1,0.1)	-	N(0.2,0.1)	-

2.4.5 HFC and PFC emissions from refrigeration and air conditioning

Emissions from refrigeration and air conditioning (both stationary and mobile) were estimated using Tier 2 top-down model as described in Forte, McCulloch & Midgley (2000 pp. 3.100-3.106). Emissions were calculated using the following equation (the approach is the same that was used for electrical equipment):

$$E = S - C - D$$

where *S* is the annual sales of new refrigerant, *C* is the net increase in total refrigerant charge and *D* is the amount of refrigerants destroyed.

The net increase in total refrigerant charge is expressed as the difference between new and retiring refrigerant charges:

$$C = NC - RC$$

where NC is the sum of full charges of new equipment (note that it includes also existing equipment converted to a new refrigerant), and RC is the sum of the original full charges of retiring equipment.

Annual sales S are defined as follows:

$$S = M + I + IP - E - EP$$

where M is the amount of domestically produced refrigerants destined for use in manufacturing, installing or servicing refrigeration and air conditioning equipment; I is the amount of imported bulk refrigerants; IP is the amount of refrigerants imported in refrigerant-containing equipment; E is the amount of exported bulk refrigerants and EP is the amount of refrigerants exported in refrigerant-containing equipment. Note that refrigerants may be mixtures of several compounds, and in case of these refrigerants, only their HFC and PFC components are included in calculations.

There is no production of HFCs or PFCs in Finland, M is thus equal to zero. Moreover, the methodology is simplified by the following assumptions:

- Because of the recent introduction of HFC and PFC containing refrigerants, these are not yet being destructed in significant quantities, and the destructed quantity D is thus equal to zero.
- For the same reason, C is approximately equal to NC , that is, $NC \gg RC$.

Given that $M = D = RC = 0$, actual emissions from stationary refrigeration and air conditioning equipment are

$$E = I + IP - EP - NC$$

It should be noted that assumptions regarding D and RC become invalid in future. Therefore the data gathering for this source category includes an element to monitor this modeling aspect: companies are asked to provide data on their deliveries of refrigerants for destruction.

Uncertainty was simulated assuming normal distributions for I , IP , E , EP and NC with means equal to survey results (see section 3.2 p. 20) and standard deviations of 2.5% of the mean.

Emissions from refrigeration and air conditioning were reported in the Common Reporting Format as a single figure for all of the refrigeration and air conditioning sub-categories (domestic, commercial, industrial, mobile, etc.). This follows from a project finished in 2002 that looked for ways of reducing companies' reporting burden (Oinonen 2002). Based on the project's results, it is clear that not all companies have statistics available for the disaggregated reporting, or that such reporting would entail an excessive burden. It was also clear that a simplified survey form yielded better response activity (see Figure 2.5-2 p. 17).

2.4.6 HFC emissions from aerosols and one-component polyurethane foam

The model for calculating emissions of HFCs from aerosols is described in the Good Practice Guidance (Forte et al. 2000 p. 3.85) as follows:

$$AE_t = fS_t + (1 - f)S_{t-1}$$

where AE_t is HFC propellant actual emissions from aerosols in year t , S_t is the amount of HFCs sold in aerosol products in year t , S_{t-1} is the amount of HFCs sold in aerosol products in year $t-1$, and f is an emission factor describing the period of time between sales and release. The Good Practice Guidance refers to Gamlen et al. (1986) who used $R(A)_t = 0.5 S(A)_t + 0.5 S(A)_{t-1}$ to approximate release from aerosols. Gamlen et al. chose 0.5 by reference to a late 1970's paper suggesting an average time lag of 6 months between sales and release. The 6 months lag referred to market situation in U.S. at that time, but referring to similar studies made in Italy, Germany, France and

U.K., Gamlen et al. concluded that 6 months is supported by the European studies as well. They also concluded that based on that data, the uncertainty in the 6-month figure is not more than 1 month.

The figure of 0.5 (or 50%) is suggested in the Good Practice Guidance as a default value. The model thus is, in other words, that aerosol emissions in year t are equal to the average of sales in two subsequent years, namely t and $t-1$. As there are no published studies in Finland that would give information on a national value for f , the default of 0.5 was chosen for calculations. A normal distribution with a mean and standard deviation of 0.50 and 0.04, or $N(0.50,0.04)$, respectively, was used in assessing the uncertainty for this source. The choice of standard deviation is based on directly applying the Gamlen et al. 1/6 uncertainty to 0.5, and assuming a normal distribution (cf. Galbally et al. 2000 p. A1.9 on selecting probability density functions), i.e. $1/6 \times 1/2 \times 1/2 \approx 0.04$. For sales data, the reporting accuracies and other data (e.g. proportion of sales exported), provided by the respondents, were used to determine normal distributions (in units of kt CO₂-eq.) of $N(89,1)$ and $N(60,1)$ for 2000 and 2001, respectively.

Potential emissions were calculated according to Tier 1a and 1b models described in the Guidelines (Anon. 1997 pp. 2.47–2.50).

Products included in the inventory were sprays for freezing, electronics testing and dusting, metered dose inhalers for treating asthma and other lung diseases as well as one-component polyurethane foam (OCF). OCF is an aerosol-like product and have been treated as such in the Finnish inventory (a practice predating the Good Practice Guidance). In the Good Practice Guidance, OCF is discussed together with other foam types, and the model is slightly different from that applied to aerosols. It has been decided not to change the practice of including OCF in the aerosols sub-source category. This would require recalculation of both aerosol and foam time series, and the recalculation would lead to insignificant differences in total Finnish emissions of F-gases.

2.4.7 HFC emissions from foams

Blowing agent HFC emissions in Finland result from the manufacturing and use of extruded polystyrene (XPS), polyurethane (PU) integral skin foam, PU appliance foam, injected PU foam and PU panels. Most of the production has been based on hydrocarbons since the phasing out of CFCs and HCFCs. Some smaller producers decided to use HCFCs for as long as possible, and then switched to HFCs. Open-celled foams (soft foams) have not been produced in Finland with HFCs.

Emissions of HFC-134a used as foam blowing agent were calculated using the Tier 2 model described in the Good Practice Guidance (Forte et al. 2000 pp. 3.93–3.95):

$$AE_{t,i} = f_{M,i}M_{t,i} + f_{B,i}B_{t,i} + R_{t,i} - D_{t,i}$$

where $AE_{t,i}$ are HFC blowing agent (actual) emissions from foam type i in year t , $f_{M,i}$ is the emission factor describing manufacturing and first year losses for the given foam type (note that emission factor is assumed time-independent), $B_{t,i}$ is the amount of HFC blowing agents banked in foams of type i in year t , $f_{B,i}$ is the emission factor describing HFC blowing agent losses from foam of type i in use, $R_{t,i}$ are the HFC blowing agent losses occurring during decommissioning of retiring foam products of type i in year t , and $D_{t,i}$ is the amount of HFC blowing agents destroyed in year t (recovered from foams of type i). For the purposes of this document, the notation was modified from that used in the Good Practice Guidance.

Given the recent introduction of HFC blowing agents and the long average lifetime of foam products, both $R_{t,i}$ and $D_{t,i}$ were taken to equal zero:

$$R_{t,i} = D_{t,i} = 0, \quad t \leq 2001$$

Unfortunately, Good Practice Guidance and the Guidelines give little advice on how to estimate $B_{t,i}$, the amount of blowing agent banked in given type of foam in given year (new blowing agent introduced to the bank annually, as well as the effect of leakage from products in use, should be modeled into the equation). In the Finnish inventory, the amount of blowing agent banked in foams was modeled as

$$B_{t,i} = (1 - f_{M,i}) \sum_{n=0}^j M_{t-n,i} - \sum_{n=0}^j E_{t-n,i} - \sum_{n=0}^j IP_{t-n,i} - f_{B,i} \left((1 - f_{M,i}) \sum_{n=0}^j M_{t-n,i} - \sum_{n=0}^j E_{t-n,i} - \sum_{n=0}^j IP_{t-n,i} \right)$$

That is, the amount of HFC banked in a given type of foam in year t in Finland equals the total amount of that HFC blown into that type of foam since the introduction of that blowing agent, and not emitted during manufacturing, $(1 - f_{M,i}) \sum_{n=0}^j M_{t-n,i}$, less the amount that was exported in products manufactured in Finland, $\sum_{n=0}^j E_{t-n,i}$, plus the amount that was imported to Finland contained in products manufactured elsewhere, $\sum_{n=0}^j IP_{t-n,i}$, less the amount that has escaped from foam during use, $f_{B,i} \left((1 - f_{M,i}) \sum_{n=0}^j M_{t-n,i} - \sum_{n=0}^j E_{t-n,i} + \sum_{n=0}^j IP_{t-n,i} \right)$.

Actual emissions from foam type i in year t are thus given by

$$AE_{t,i} = f_{M,i} M_{t,i} + f_{B,i} \left((1 - f_{M,i}) \sum_{n=0}^j M_{t-n,i} - \sum_{n=0}^j E_{t-n,i} + \sum_{n=0}^j IP_{t-n,i} - f_{B,i} \left(\sum_{n=0}^j M_{t-n,i} - \sum_{n=0}^j E_{t-n,i} + \sum_{n=0}^j IP_{t-n,i} \right) \right)$$

Total HFC blowing agent emissions from all foam types in year t are then given by

$$AE_{tot,t} = \sum_{i=1}^k AE_{t,i}$$

The model is dependent on the use of emissions factors for each foam type. Since such national factors were not available, IPCC default factors were used (Forte et al. 2000 p. 3.96). The factors (probability density functions) used are shown in table 2.4-2 below. Uncertainties related to activity data are discussed in the results section (section 3.4 p. 24).

Table 2.4-2: Probability density functions used in simulating HFC blowing agent emissions. $f_{M,i}$ is the manufacturing and first year loss emissions factor, while $f_{B,i}$ is used to estimate blowing agent diffusion out of foams in use. N = normal distribution, with mean (m) and standard deviation (s) given in parenthesis $N(m,s)$.

i	Foam type	$f_{M,i}$	$f_{B,i}$
1	XPS	N(0.40,0.08)	N(0.030,0.006)
2	PU integral skin	N(0.95,0.20)	N(0.025,0.01)
3	PU injected	N(0.125,0.020)	N(0.005,0.01)
4	PU appliance	N(0.075,0.020)	N(0.005,0.01)
5	PU discontinuous panel	N(0.125,0.020)	N(0.005,0.01)

Potential emissions were calculated according to Tier 1a and 1b models described in the Guidelines (Anon. 1997 pp. 2.47–2.50).

2.4.8 HFC emissions from fixed fire fighting systems

The Good Practice Guidance states that it is good practice "to model emissions based on a top-down approach similar to that used by the Montreal Protocol Halons Technical Options Committee for estimating emissions of halons." (Forte et al. 2000 p. 3.115) But, until this model becomes available, the Guidance recommends using an approach similar to that described for stationary refrigeration and mobile air conditioning.

There is, however, only one company that has sold HFC-containing fixed fire fighting equipment since 1997. During 2001 another company started to import HFC-containing equipment. There is also a third company that is considering entering the market, but no activity has taken place yet. All of the equipment sold in Finland have been manufactured elsewhere.

In case of Finland, the most accurate method of emission estimation is to use the company's statistics on quantities released during actual incidences of fire (there has been no re-filling of systems due to other reasons than fire). In 2001, the quantity of extinguishing agent refilled amounted to 0.1% of the installed bank. Extinguishing agent emitted over the entire history of HFC-containing equipment usage amounts to some 0.7% of installed bank. None of these systems have been decommissioned yet. (Heikkilä 2002) Moreover, diffusion through system components is considered negligible. Uncertainty of the emission estimate was assumed as $\pm 5\%$ and normally distributed. Potential emissions were calculated according to Tier 1a and 1b models described in the Guidelines (Anon. 1997 pp. 2.47–2.50).

Since the statistics of actual releases became available, it is clear that previous emission estimates for this source category have been over-estimated. Recalculations following from improved data are treated together with other confidential data in section 3.10.

2.4.9 Summary of the models used

The models used in the inventory are summarized in table 2.4-3 below.

Table 2.4-3: A summary of the models used for each of the source categories.

Source category	Models used	Reference	Notes
Magnesium die-casting	Direct reporting method, Tier 1a	Palmer 2000 p. 3.48; Anon. 1997 p. 2.47	Tier 1b is not applicable to this category because all SF ₆ used is imported in bulk. Emissions from this source are not reported separately due to confidentiality.
Electrical equipment	Tier 3c (country-level mass-balance), Tier 1b	Olivier & Bakker 2000 p. 3.56; Anon. 1997 p. 2.48 and section 3.1 of this report	Tier 1a estimates cannot be calculated for this source because of lack of historical data. Tier 1b estimates have been calculated, however, based on survey and emissions data.
Running shoes	Model for adiabatic property applications, Tier 1b	Olivier & Bakker p. 3.65; Anon. 1997 p. 2.48	Tier 1a is not applicable to this category because all SF ₆ used is imported in products. Emissions from this source are not reported separately due to confidentiality.
Semiconductor manufacturing	Tier 1, Tier 1a	Bartos & Burton 2000 p. 3.72; Anon. 1997 p. 2.47	Tier 1b is not applicable to this category because all gases used are imported in bulk.

Source category	Models used	Reference	Notes
Refrigeration and air conditioning	Top-down Tier 2, Tier 1a, Tier 1b	Forte et al. 2000 pp. 3.100–3.106; Anon. 1997 pp. 2.47–2.50	Tier 2 top-down model is used for all sources in this category, both stationary and mobile. Data is not collected for separate sub-categories (domestic, commercial, industrial, etc.) because such statistics either are not available, or the preparation of such statistics by companies would entail a very high reporting burden. HFC-23 emissions from this source are not reported separately due to confidentiality.
Aerosols and one-component foam	Tier 2, Tier 1a, Tier 1b	Forte et al. 2000 p. 3.85; Anon. 1997 pp. 2.47–2.50	One-component foam cans are treated as aerosols in this inventory, cf. section 2.3.6. MDIs are not reported separately from other aerosols due to confidentiality.
Foam blowing	Tier 2, Tier 1a, Tier 1b	Forte et al. 2000 p. 3.93 and section 2.3.7 of this report; Anon. 1997 pp. 2.47–2.50	IPCC Revised Guidelines and the Good Practice Guidance give little advice on how to model the effect of leakage from products, and the annually installed new foam products, on HFCs banked in foams. See section 2.3.7 of this report on how these effects were modeled.
Fixed fire fighting systems	Tier 2, Tier 1a, Tier 1b	Forte et al. 2000 p. 3.115 and section 2.3.8 of this report; Anon. 1997 p. 2.47–2.50	Emissions from this source are not reported separately due to confidentiality.

2.5 Sources and gathering of data

This section of the report describes the sources of data pertaining to 2001, as well as the gathering of data from these sources. The gathering of data took place over a period of several months in 2002. The timing was designed to take into account special features of the sectors. For instance, the summer months in refrigeration and air conditioning industry are very busy, so this time of the year was not used for data gathering. Most of the responses (99%) were obtained during a period from February to May, March and April being the months of highest activity (Figure 2.5-1). The survey was terminated in August. Survey forms were sent to 247 companies, 215 of which responded, yielding an overall response rate of 87%.

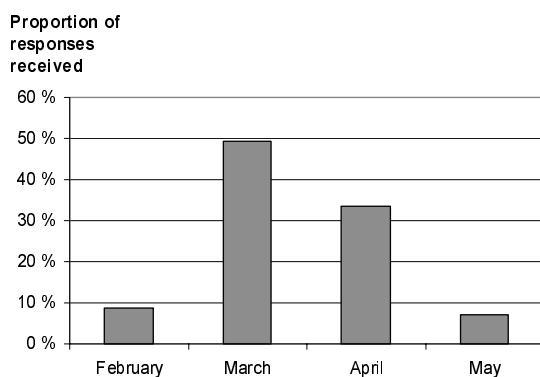


Figure 2.5-1: Data gathering took place mostly in a period from February to March 2002. Most of the responses were received in March and April. The data-gathering phase of the inventory was terminated in August.

2.5.1 SF₆ emissions from magnesium die-casting

Only one producer exists in Finland currently. The data is obtained directly from the Quality, Environment, Health and Safety Manager of the company. The data consists of annual consumption of SF₆ used as cover gas.

2.5.2 SF₆ emissions from electrical equipment

Activity data for SF₆ emissions from electrical equipment is obtained from manufacturers and importers of the equipment in Finland, as well as importers of gas. The survey forms were sent to 6 equipment importers and manufacturing companies in Finland. All of the companies responded; one of them turned out to be irrelevant given the method used to calculate emission. The results of the survey also indicate that there may be one other potential importer, which was not covered by the survey. This company will be surveyed in 2003. Four companies importing specialty gases were also surveyed. Three of these replied and the one remaining did not provide an answer despite of several attempts. The non-responding company will be contacted again in 2003.

The data gathered consists of gas quantities used for manufacturing, imported (in bulk and in equipment), exported (in bulk and in equipment), sales of equipment and gas for end-use (both equipment that is charged at the manufacturing site and equipment that is filled during installation).

2.5.3 SF₆ emissions from other sources

Statistics on shoe sales were obtained from the company importing the shoes. The statistics cover a period from 1978 to 2001. The company has estimated shoe sales statistics for 1978–1996. More reliable data is available for 1997–2001. The statistics consist of pairs of shoes sold and do not deviate between SF₆-containing and other shoes. This is a new source that was added to the inventory this year. Recalculations were performed accordingly, cf. section 3.10 p. 30.

2.5.4 HFCs, PFCs and SF₆ from semiconductor manufacturing

Data on gas consumption for semiconductor manufacturing was obtained directly from the end-users. Survey forms were sent to 3 companies, 6 universities and 2 research institutes. Except for one research institute, all of these replied. During the survey, one respondent indicated that there might be one company that was not covered. The quality manager of this company was contacted with a request for information, but data on gas consumption, or confirmation that this company indeed manufacture semiconductors, could not be obtained. The company will be contacted again in 2003.

2.5.5 HFCs and PFCs from refrigeration and air conditioning

A survey of 185 companies was used as a source of data for refrigerants and products that may contain both refrigerants and foam blowing agents. The group of companies includes manufacturers and importers of domestic refrigeration equipment, companies that import passenger cars, vans, trucks and buses, importers and manufacturers of other air conditioning and refrigeration equipment, importers of bulk refrigerants, contractors and service companies.

The data gathered consists of gas quantities imported and exported in bulk and in products, quantities used for manufacturing, quantities used to install new refrigerant capacity (new equipment and conversion of old equipment to a new refrigerant) and quantities sent for destruction.

The companies were active in responding to the survey. The response rate exceeded 80% (Figure 2.5-2). On the other hand, there were also companies that refused to answer the survey on the grounds that it is not mandatory to do so. Following a project aiming to reduce the companies' reporting burden (for instance, by designing a simpler survey form and by improving guidance on answering), the response rate was higher than the year before.

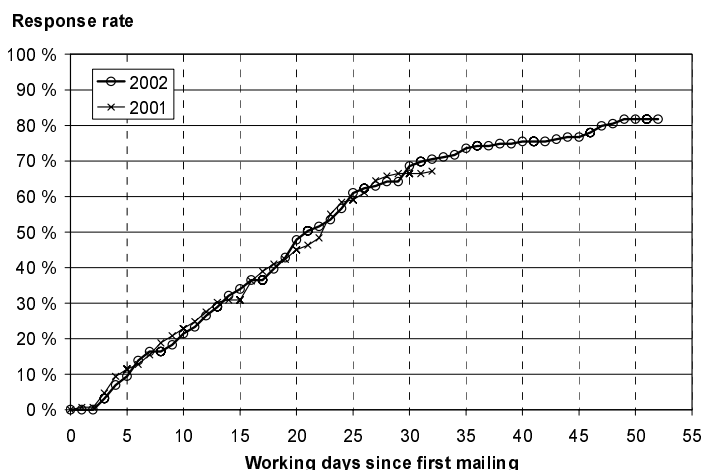


Figure 2.5-2: Development of response rate as a function of working days since first mailing of the survey forms. Also shown is a comparison between 2001 and 2002. The companies were reminded three times both in 2001 and 2002. The higher response rate in 2002 is attributed to a simpler survey form and improved guidance on how to fill in the form, as well as a brief document explaining the purpose of the survey.

2.5.6 Aerosols and one-component foam

Importers, exporters and manufacturers of aerosols were surveyed for activity data. The survey form was sent to 25 companies, 23 of which replied. The two non-responding companies will be surveyed again in 2003. The companies were asked to provide data on the types and numbers of aerosols they import, which HFC is used as a propellant, and the quantities used for manufacturing. The companies were also asked to provide data on exports.

2.5.7 HFCs from foam blowing and foam products

Activity data used in the inventory were obtained through a survey of companies engaged in foam blowing, import and export of materials for foam blowing, and imports and exports of foam containing products. The survey form was sent to 46 companies altogether (including 18 companies that received also a questionnaire on refrigerants). The response rate was very high, 91% of companies sent their replies.

The data consists of imports and exports of foam blowing agents and products containing these agents (in final products such as fridges and also in polyol used to manufacture insulation for such equipment), quantities used for manufacturing and the types of foams manufactured.

2.5.8 HFCs from fixed fire fighting systems

Data on HFCs used as extinguishing agents in fixed fire fighting systems were obtained directly from the company importing and installing the equipment. The data consists of imported quantities, quantities installed as new capacity and quantities used to compensate for gas consumed in actual cases of fire.

2.6 Recalculation methods

Recalculation was carried out in this inventory because of

- Addition of a new source (SF₆ from shoes)
- Change of methodology (SF₆ from electrical equipment and HFCs, PFCs and SF₆ from semiconductor manufacturing), and
- Improved data (HFCs from fixed fire fighting systems).

Methods used to recalculate the time series were overlap (electrical equipment) and extrapolation (semiconductor manufacturing). The use of these methods is necessary due to lack of historical data. Better data are available for SF₆ from shoes and HFCs from fixed fire fighting systems, and consequently there is no need for use of such adjustment methods. The details and results of recalculation are described in section 3.10 (p. 30).

2.7 Treatment of confidential data

The models used to calculate potential and actual emissions of HFCs, PFCs and SF₆ are based on data obtained directly from corporate entities, universities and research institutions. These sources of data have responded to annual surveys providing information on, for instance, chemical quantities imported, exported and used in manufacturing products. The data gathering has been based on voluntary inquiries and a promise not to disclose confidential information, or to report results in a manner that confidential information could be inferred.

Although there can be no absolute safeguards against breaches of confidentiality, care has been taken not to publish or otherwise release identified or identifiable data. To lessen the likelihood of such breaches, reporting has been based on anonymity. Moreover, to counteract the opportunities for others to infer confidential information, grouping of activity and emissions data have been carried out.

Because of the multidimensional structure of the tables in the Common Reporting Format—emissions (and activity data in case of sector-specific background data tables) are reported disaggregated to sub-source categories, to individual chemical species, to manufacturing, use and disposal emissions, to emissions calculated using different methods (Tier 1a, 1b, 2)—the grouping in many cases becomes an inadequate strategy to safeguard against breaches of confidentiality. The number of respondents is simply too small in certain categories to support such disaggregation. For this reason it has not always been possible to report emissions on the most disaggregated level for a source category (paragraph 19 in UNFCCC Guidelines on Annual Inventories, FCCC/SBSTA/1999/6/Add.1). In order to facilitate the assessment of completeness, the cells for which data cannot be reported due to confidentiality, have been marked with "C" (paragraph 21.(e) of the Guidelines on Annual Inventories).

In the previous inventories, confidential data have been grouped over sub-source categories in order to include the emitted quantities, and to enable the data flow from sector-specific report tables to summary tables. This does, however, inflict some damage to analysis possibilities, because components of emissions have been moved from one category to another. For instance, HFC-152a emissions from aerosols have been aggregated with HFC-152a emissions from refrigeration and air conditioning. With many such transfers from one category to another, the entire categorization soon begins to lose its meaning. It is also a question of consistency if grouping over categories is carried out on an annual basis, and if the allocation of emissions to categories varies from one year to another. Moreover, also comparability becomes an issue: because a

component of emissions from aerosols are confidential, emissions from aerosols in Finland cannot be compared to emissions from aerosols, say, in Denmark. Moreover, if one-component of emissions from aerosols is added to emissions from refrigeration and air conditioning, this emission category also becomes non-comparable.

In order to minimize these damages to analysis possibilities, the grouping practice over categories has been given up. All confidential emissions data have been grouped and added to figures in the summary tables. Also, classification of one species-source category combination is kept constant over all inventory years. This means that a combination may be confidential in one year and not in the second year, but the combination for both years is classified confidential for the sake of consistency. These practices are hoped to inflict minimum damage to the usefulness of categorization, consistency and comparability.

It should be noted that although every effort to protect the sources of data have been taken, the possibility of disclosing confidential information can not be ruled out entirely. For example, it is possible to envisage a situation where the end-users of a certain chemical are numerous, but the importers of the chemical are few. In such a case, if only the end-users are surveyed, and not the entire chain of production, it is possible that the data is not confidential in case of the end-users, but it may be connected to the activity of just one or two importers.

2.8 Quality assurance and control

Quality assurance and control is under development for the F-gases inventory as a part of the work carried out for the overall Finnish inventory of greenhouse gases. At present, quality control is applied, for instance, to the process of transferring data from calculation sheets to Common Reporting Format tables. Personnel in charge of compiling the overall inventory from sector-specific results carry out these order of magnitude and other checks.

3 RESULTS AND DISCUSSION

3.1 SF₆ emissions from electrical equipment

Results of the manufacturer and importer survey (section 2.5.2 p. 16) for 2001 are shown in Table 3.1-1 below. All 6 companies responded. The errors of ± 0.06 tons were assessed from the data.

Table 3.1-1: Results of the electrical equipment survey. Q = quantity of SF₆ in metric tons, N = number of companies behind Q for each activity, NO = not occurring and C = confidential.

Activity	SF ₆	
	N	Q/t
Imported in bulk	2	C
Imported in products	4	0.58 \pm 0.06
Exported in bulk	NO	NO
Exported in products	1	C
Sold in equipment for use in Finland	5	0.61 \pm 0.06
Nameplate capacity of non-factory charged equipment sold for use in Finland	1	C
Used for manufacturing	1	C

Application of the equations for Tier 1a and 1b and Tier 2 (section 2.4.2 p. 8) to data in Table 3.1-1 (and also using the confidential figures not shown) yields the emissions estimates reported in Table 3.1-2. Because there were only 2 companies behind imports of SF₆ for use in electrical equipment, Tier 1a emissions could not be tabulated.

In case of the Tier 2 estimate the upper and lower bounds of the 95% confidence limit are non-symmetrical. This is because one of the input distributions used in simulation was positively skewed (annual growth of new nameplate capacity, cf. section 2.4.2). Median of the simulation results is reported as the emission estimate.

Table 3.1-2: Potential and actual emissions of SF₆ from electrical equipment in 2001. Confidential data is marked with 'C'.

Model	Emission in 2001	
	t	Gg CO ₂ -equivalent
Tier 1a	C	C
Tier 1b	2.21 \pm 0.11	53 \pm 3
Tier 2	1.5 (1.4 ... 1.8)*	36 (33 ... 43)*

*The range is given by 2.5 percentile (lower bound) and 97.5 percentile (upper bound).

Uncertainty of the 1990 Tier 2 estimate is very difficult to quantify. It was simply assumed for the purpose of assessing trend uncertainty, that the estimate is associated with 50% uncertainty which is normally distributed around the mean (3.6 metric tons SF₆). Results suggest that the change in emissions from 1990 to 2001 was -1.5 metric tons (-4.2 to 1.9 metric tons with 95% certainty). Likelihood that the change was negative (i.e. emissions decreased) exceeded 80%.

3.2 HFC and PFC emissions from refrigeration and air conditioning

Results of the survey of companies operating in refrigeration and air conditioning industry (section 2.5.5 p. 16) are shown in Table 3.2-1.

Table 3.2-1: Results of the refrigeration and air conditioning survey. Please note that all activity data related to refrigerants have been broken down according to refrigerant composition; only HFC and PFC components of the refrigerants are shown. The number of respondents behind each figure is not shown due to space constraints.

Activity	Quantity in metric tons						
	HFC-23	HFC-32	HFC-125	HFC-134a	HFC-143a	HFC-152a	PFC-218
Refrigerants imported in bulk	C	12.4±0.6	110±6	200±10	104±5	5.0±0.3	3.46±0.17
Refrigerants imported in equipment	NO	2.12±0.11	3.3±0.2	74±4	1.2±0.6	NO	NO
Refrigerants exported in bulk	NO	0.57±0.03	7.4±0.4	5.8±0.3	7.8±0.4	0.3±0.1	0.39±0.02
Refrigerants exported in equipment	NO	0.0480±0.002	1.7±0.9	7.9±0.4	1.98±0.10	NO	NO
New refrigerant capacity	NO	6.2±0.3	53±3	97±5	51±3	1.03±0.05	0.243±0.012

Figures for new refrigerant capacity in Table 3.2-1 are shown uncorrected for non-response and under-coverage. Based on experiences from past inventories and discussions with refrigerant importers, it is likely that all imports and exports of bulk refrigerants are covered by the survey. Although with less certainty, the same is assumed for imports and exports of refrigerants in equipment. Installation of new systems, and conversion of existing systems to new refrigerants on the other hand, is directly affected by both non-response and under-coverage. This is because it is known that the total number of companies far exceeds those included in the survey.

The contact details of companies that install and service equipment became available in 2002.³ In all, there are some 850 companies that manufacture, sell, install, repair and service equipment. Some 40% of these are companies that service only equipment with a refrigerant charge less than 3 kg. There may thus be approximately 300 companies outside the survey that install new refrigerant capacity annually.

For the argument's sake, let us assume that the new capacity as shown in Table 3.2-1 is indeed an underestimate. It follows then—given the model used to quantify emissions—that emissions are overestimated. For the purpose of illustrating the effect of this uncertainty to the emission estimate, the new capacities were multiplied by a correction factor (Figure 3.2-1). The factor aimed to account for the fact that the capacity was at least that reported by the companies participating in the survey, but that it also may be an underestimate.

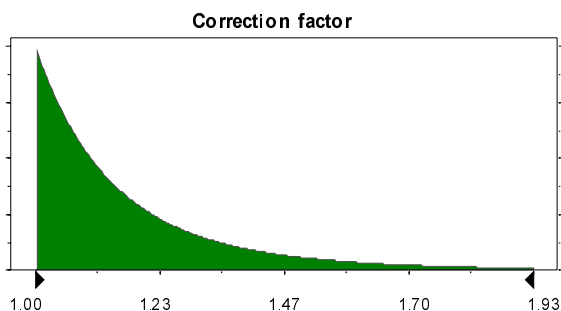


Figure 3.2-1. Pareto distribution used to account for uncertainties in the new refrigerant capacity parameter.

³ The list is related to Government decree 1187/2001 concerned with qualifications of personnel allowed to service equipment.

In simulation, all figures of Table 3.2-1 were replaced by normal distributions, means as shown in the table and standard deviations approximately half of the uncertainties reported in the table. Results of the simulations are shown in Table 3.2-2.

Table 3.2-2. Simulation results for HFC and PFC emissions from refrigeration and air conditioning. Results are reported as median of simulated emissions for each species. Figures in parenthesis give the 95% confidence interval defined by the 2.5 and 97.5 percentiles. Confidential HFC-23 figures are included in grouped data, section 3.5.

Model	Emissions in Gg CO ₂ -equivalents						
	HFC-23	HFC-32	HFC-125	HFC-134a	HFC-143a	HFC-152a	PFC-218
Tier 1a	C	7.7 (7.3...8.1)	290 (270...300)	250 (240...260)	370 (350...390)	0.67 (0.64...0.70)	21 (20...23)
Tier 1b	C	9.1 (8.7...9.5)	290 (280...310)	340 (320...350)	360 (350...380)	0.67 (0.64...0.70)	21 (20...23)
Tier 2	C	4 (2...5)	150 (20...150)	220 (100...220)	170 (0...180)	1 (0...1)	19 (18...21)

The use of pareto distribution is shown as skewness in the Tier 2 results. Thus, given that correct parameters were chosen for the distribution, it is possible, although not very likely, that emissions could be as low as the lower limit given in parentheses.

The simulated Tier 2 estimates as shown in Table 3.2-2 were *not* reported to the UNFCCC. Instead, point estimates were used to fill the Common Reporting Format tables. The results of the simulation given above should be thought of as an illustration of the kind of uncertainties that might be involved in calculating Tier 2 emissions from refrigeration and air conditioning. Nevertheless, this exercise was useful in pinpointing the one parameter of the calculation model, which is the source of most uncertainty in the estimates. In the inventory for 2002, the data gathering will be expanded so that it is not necessary to correct the parameter values for new capacity, and much of the uncertainty will thus be eliminated.

The total simulated emissions of all HFCs and PFC-218 from refrigeration and air conditioning amounted to

- Tier 1a = 940 (910...970) Gg CO₂-eq.
- Tier 1b = 1030 (1000...1060) Gg CO₂-eq.
- Tier 2 = 500 (100...600) Gg CO₂-eq.

The Tier 2 point estimate reported to UNFCCC was approximately 550 Gg CO₂-eq. The difference in estimates is explained by the pareto distribution used in simulation, which "shifts" the median towards the lower bound.

The difference between Tier 1a and 1b emissions is largely explained by the difference in HFC-134a estimates, which is the refrigerant that is being imported and exported in products. Imports and exports of other refrigerants in products are far smaller. Typical examples of equipment containing HFC-134a when crossing Finnish border include domestic refrigeration equipment, smaller air conditioning equipment and heat pumps, and last but not least, mobile air conditioning systems in cars.

The results also show that depending on the model used, emissions range from 100 to just over 1000 Gg CO₂-eq. The Tier 1b model gives an upper limit to annual emissions of HFCs and PFC-218 from refrigeration and air conditioning equipment. It is likely that true emissions are much lower, somewhere within the upper part of the range quoted for Tier 2 above.

The results thus indicate that Tier 1 or 1b should not be used for inventory purposes to report emissions, given the aim of accuracy stated in the reporting guidelines. More confidence can be placed on the Tier 2 estimate.

Because of the virtually non-existing emissions from refrigeration and air conditioning in 1990, calculation of trend between 1990 and 2001 would not give a meaningful result. The time series of emissions is discussed in section 3.7.2 below (p. 26).

3.3 HFC emissions from aerosols and one-component polyurethane foam

Results of the aerosol survey for 2001 are shown in Table 3.3-1 below. Only 2 of the 25 companies surveyed did not respond, yielding a response rate of 92%. Of the 23 respondents, 9 companies reported that they did not import nor sell HFC-containing aerosols in 2001, i.e. their aerosols were based on other propellants, such as propane and butane. Three of the companies contacted were retailers. Quantities sold by the retailers were purchased from importers and manufacturers included in the survey, and—in order to avoid double counting—were not included in the sales figures of Table 3.3-1. Errors reported in the table were estimated from responses received.

Quantities used for manufacturing were slightly higher than quantities imported in bulk, reflecting changes in manufacturers' stocks. Nearly 60% of the quantity used for manufacturing was exported from the country within products.

Table 3.3-1: Results of the aerosol survey. Q = quantity of given HFC in metric tons, N = number of companies behind Q for each activity, and C = confidential.

Activity	HFC-134a		HFC-152a		HFC-134a + HFC-152a	
	N	Q/t	N	Q/t	N	Q/t
Imported in bulk	4	C	1	C	5	130.6±1.1
Imported in products	5	12.337±0.011	2	0.666±0.004	6	13.00±0.02
Exported in bulk	NO	NO	NO	NO	NO	NO
Exported in products	2	C	2	C	4	79±1.0
Sold in products	9	46.96±0.02	3	21.0±1.0	11	68±1.0
Used for manufacturing	4	C	1	C	5	133.8±1.1

Application of the equations for Tier 1a and 1b and Tier 2 to data in Table 3.3-1 yields the emissions estimates reported in Table 3.3-2. (Calculation of CO₂-equivalent emissions requires information on the imported and exported quantities, which are confidential—marked with C in Table 3.3-1. It should also be noted that manufacturing, destruction and bulk export of HFC propellants did not take place in 2001. Potential Tier 1a estimate thus equal bulk chemical imports for manufacturing of aerosols.)

The results of the inventory suggest that Tier 1a should simply be rejected as a model not suitable for describing HFC-emissions from aerosols. The model is only valid for special situations (e.g. when imported and exported quantities cancel out). In the case of Finland for instance, Tier 1a emissions have been far greater than Tier 1b or 2 emissions. This is due to considerable amount of HFCs exported from the country in manufactured products. Failing to account for imports and exports could thus lead to considerable error.

Table 3.3-2: Potential and actual emissions of HFC-134a and HFC-152a from aerosols in 2001.

Model	Emissions in 2001	
	metric tons	Gg CO ₂ -equivalent
Tier 1a	130.6±1.1	90.9±0.8
Tier 1b	65±2	60±2
Tier 2	76±2	74±2

3.4 HFC emissions from foams

Results of the foam blowing survey are shown in Table 3.4-1. The survey response rate was 87%, only 4 of the 46 respondents did not respond. Many of the companies were not involved in activity associated with HFCs. The activities of these companies were based on other blowing agents, such as hydrocarbons.

Table 3.4-1: Results of the foam blowing survey. N = the number of respondents, Q = the quantity of HFC-134a consumed in given activity in 2001.

Activity	HFC-134a	
	N	Q/t
Imported in bulk or in polyol	5	73±4
Imported in products	4	33±2
Exported in bulk	NO	NO
Exported in products	8	8.4±0.5
Used for manufacturing	11	80±4

Application of the methodologies described in section 2.4.7 to activity data presented in Table 3.4-1, and – in case of Tier 2 – also to the previous years' activity data (not shown), yield the emissions estimates given in Table 3.4-2.

In case of foam blowing, considerable amounts of gas is imported and exported in products annually, which is shown by the difference between Tier 1a and 1b figures. Some of the gas is also contained within the manufactured products and diffuses slowly into the atmosphere. Tier 1 models thus over-estimate emissions considerably. This is demonstrated by the result of actual (Tier 2) emissions.

Table 3.4-2: Potential and actual HFC-134a emissions from foam blowing and foam products in 2001.

Model	Emissions in 2001	
	metric tons	Gg CO ₂ -equivalent
Tier 1a	73±4	95±5
Tier 1b	97±6	126±8
Tier 2	40±10	52±13

3.5 Grouped HFC, PFC and SF₆ emissions data

There are sources within the F-gases inventory for which disaggregated activity and emissions data is confidential. Estimates were grouped for these sources in order prevent breaches of confidentiality. The grouping of sources and gases were carried out in a manner that enables comparison of potential and actual emissions. The potential emissions estimate consists of the Tier 1a emissions from

- HFC-23 from refrigeration and air conditioning
- SF₆ from magnesium die-casting
- HFCs from fixed fire fighting systems
- HFCs, PFCs and SF₆ from semiconductor manufacturing.

Included is also Tier 1b SF₆ emissions from running shoes.

Actual emissions were calculated for the same sources using models described under section 2.4.

In 2001, actual emissions from grouped sources amounted to 20±7 Gg CO₂-eq., whereas potential emissions from these sources amounted to 17±7 Gg CO₂-eq. Poten-

tial emissions were smaller than actual due to the model used in calculating emissions of SF₆ from shoes, which assumes a delay between emissions and sales.

3.6 Summary of emissions by source

Most of the actual emissions of F-gases (approximately 75%) came from refrigeration and air conditioning (Table 3.6-1). Aerosols and one-component polyurethane foam (OCF), together with electrical equipment and foam blowing, contributed some 22% of the emissions of F-gases. The remaining 3% came from grouped sources (HFC-23 from refrigeration and air conditioning, SF₆ from magnesium die-casting, HFCs from fixed fire fighting systems, HFCs, PFCs and SF₆ from semiconductor manufacturing and SF₆ from running shoes).

Table 3.6-1: Summary of the Finnish emissions of F-gases in 2001. The 95% confidence limits are shown in parenthesis for skewed distributions. Total F-gases emissions in 2001 equal approximately 730 Gg CO₂-eq.

Source category	Emissions in Gg CO ₂ -equivalents		
	Tier 1a	Tier 1b	Actual ^a
Electrical equipment	C	53±3	36 (33...43)
Refrigeration and air conditioning	870±30	960±30	550 (100...600) ^c
Aerosols and OCF	90.9±0.8	60±2	74 (72...77)
Foam blowing	95±5	126±8	52±13
Grouped data	17±7 ^b		20±7

^aNote that 'Actual' is used here to denote results for methods used to calculate actual emissions (by contrast, Tier 1a and 1b are methods for calculating potential emissions). Please refer to section 2.4.9 for a summary of the methods used.

^bTier 1a potential emissions from HFC-23 from refrigeration and air conditioning, SF₆ from magnesium die-casting, HFCs from fixed fire fighting systems, HFCs, PFCs and SF₆ from semiconductor manufacturing and Tier 1b SF₆ emissions from running shoes.

^cHere, a point estimate of 550 Gg CO₂-eq. is reported with an illustrative simulated uncertainty range (given in parenthesis).

In order to estimate uncertainty in the total F-gases estimate, probability density functions were fitted to simulation results summarized in Table 3.6-1. Foam blowing, aerosol and grouped data emissions were simulated with normal distributions (means as shown in Table 3.6-1 and standard deviations approximately half of the uncertainties reported). Emissions from electrical equipment and refrigeration and air conditioning could not be modeled with normal distributions because results for these two source categories were highly skewed. Both categories were modeled using extreme value distributions with modes of 35.68 and 496.62, and scales of 1.43 and 63.94, respectively.

Simulation of overall emissions in 2001 gives an estimate of 700 Gg CO₂-eq. for actual emissions. The 95% confidence interval for this estimate is 400...800 Gg CO₂-eq. Most of this uncertainty is due to uncertainty in the "new capacity" parameter of the model used to calculate emissions for refrigeration and air conditioning equipment. This uncertainty stems from under-coverage of the survey used to gather data. After implementation of new national legislation, a list of contact details was published for the first time in 2002. This eliminates much of the uncertainty in the next inventory.

3.7 Emission trends by source

3.7.1 Electrical equipment

SF₆ emissions from electrical equipment are an exception amongst the F-gases emitting sources in Finland: emissions from this source have decreased compared to 1990 (Figure 3.7-1). The cut-down in emissions is explained by the fact that SF₆ has not been used as a substitute for ozone depleting substances. It was introduced for use in electrical equipment during 1970s, and the use grew rapidly during 1980s. It seems that most of the capacity was installed before 1990s. New equipment is also less leaky compared to older equipment. The industry is also implementing voluntary measures to limit emissions, such as recovery and recycling of SF₆.

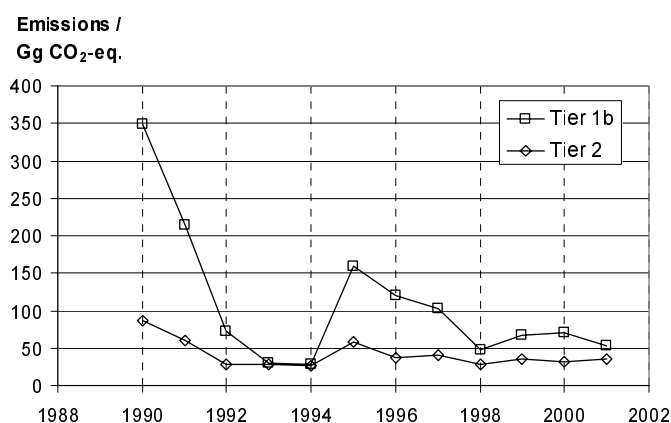


Figure 3.7-1: Time series for potential and actual emissions of SF₆ from electrical equipment.

Points in time where potential (Tier 1b) emissions come close to actual emissions (Tier 2) demonstrate years when most of the gas consumed was used to compensate for losses from existing equipment. During these years little new capacity was installed. The uncertainties associated with emissions estimates are considerable however, and this is especially the case with early 1990s emissions.

3.7.2 Refrigeration and air conditioning

The phasing-out of ozone depleting substances and their substitution by HFCs and PFCs started in early 1990s. The consumption of HFC-containing refrigerants grew rapidly during the latter part of the decade. Following the dramatic growth in consumption, also emissions started to grow. This is clearly visible in the time series for emissions from this source (Figure 3.7-2).

The flattening of the Tier 2 emissions curve from 1999 to 2000 has to do with the way one of the parameters of the emissions model is estimated. This parameter, new installed capacity of refrigerants, has been difficult to estimate because of survey under-coverage. Considerable uncertainty is associated with this estimate as discussed in section 3.2 (p. 20). A similar flattening of the consumption curve (Tier 1b) would be likely, if the flattening would truly be the result of a decrease in emissions. Some additional empirical evidence on the new capacity and its relation to total consumption of refrigerants will be obtained during 2003. This is because the inventory year 2002 is the first year for which it is possible to carry out a survey with the fullest possible coverage of relevant companies (see section 3.2 p. 20).

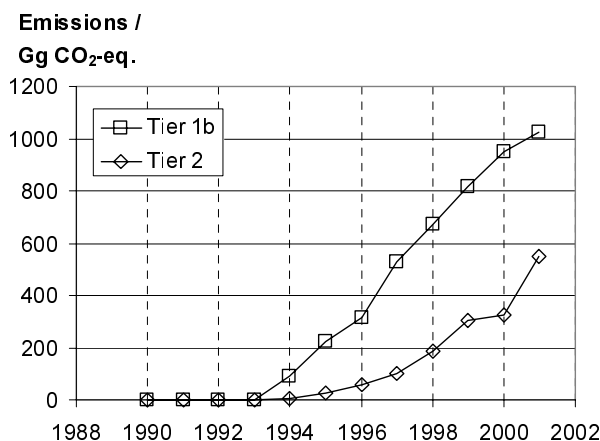


Figure 3.7-2: Time series for potential and actual emissions from refrigeration and air conditioning.

3.7.3 Aerosols and one-component polyurethane foam

Similar pattern of fast growth in emissions is depicted by the time series for aerosols and one-component polyurethane foam (OCF), Figure 3.7-3. Also the drivers behind this source are similar to refrigeration and air conditioning: substitution of ozone depleting substances by HFCs. The model used to calculate Tier 2 emissions equate emissions with the average of two consequent year's potential emissions (sales). Depending on the market dynamics, this can lead to actual emissions higher than potential, as shown in Figure 3.7-3. The sudden drop in emissions was due to substitution of some HFC-134a use by HFC-152a. The latter compound has a much lower GWP-value.

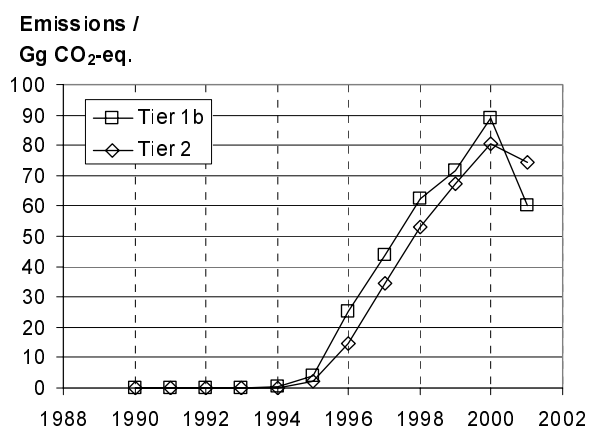


Figure 3.7-3: Time series for potential and actual emissions of HFC-134a and HFC-152a from aerosols and one-component foam.

3.7.4 Foam blowing and foam products

HFC-134a emissions from foam blowing and foam products changed rapidly between 1999 and 2000 (Figure 3.7-4). This was due to the phasing-out of HCFC-141b from January 1st 2000 onwards and its substitution by HFC-134a.

Potential emissions started to increase earlier, which was the result of HFC-134a being imported to Finland in products that have very low blowing agent emissions during use, e.g. thermal insulation panels in domestic refrigerators and freezers. Most of the emissions come from manufacturing of other foam types, however, and this is displayed by the time lag between potential and actual emission curves.

It is interesting to note that there was a decrease in consumption and emissions from 2000 to 2001, similar to that observed for aerosols and OCF. In case of foam blowing, the drop cannot be attributed to substitution, because such a change did not take place.

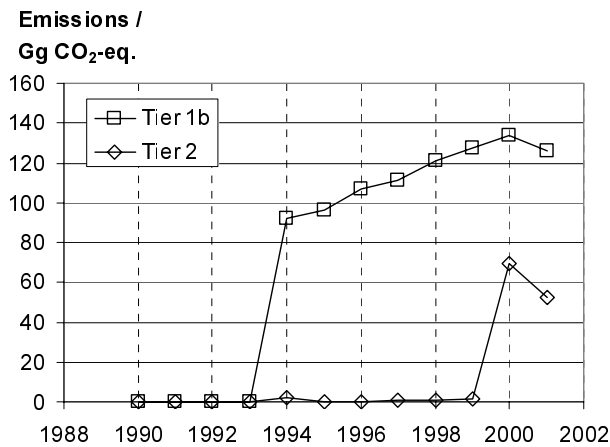


Figure 3.7-4: Time series for potential and actual emissions of HFC-134a from foam blowing and foam products.

3.7.5 Grouped data

Figure 3.7.5 shows how emissions from confidential sources have changed from year to year. Actual emissions have varied between 20 and 35 Gg CO₂-eq. since 1996. The figure also shows potential emissions smaller than actual. Reasons for this are similar to those described for aerosols: changing markets and models that equate emissions with historical consumption.

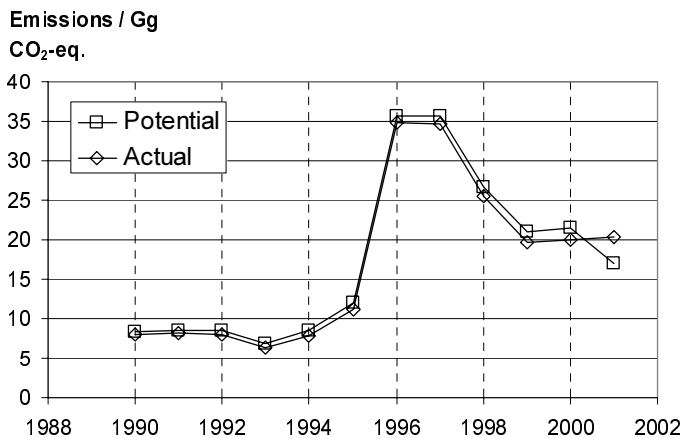


Figure 3.7-5: Time series for potential and actual emissions from confidential sources (running shoes, magnesium die-casting, fixed fire fighting systems, HFC-23 from refrigeration and air conditioning, and semiconductor manufacturing).

3.8 Emissions trends by gas

Most of the growth in emissions of F-gases has occurred due to increased emissions of HFCs. These gases have demonstrated an exponential growth in emissions (Figure 3.8-1). As discussed above, this growth is attributed to substitution of ozone depleting substances in refrigeration and air conditioning, aerosols, and foam products.

There is also a significant change in emissions of PFCs in 2000, which is explained by the introduction of a new PFC-containing refrigerant to the Finnish market.

Before that all emissions of PFCs took place due to their consumption in semiconductor manufacturing.

Emissions of SF₆ have been variable over time, but the level of emissions has not changed dramatically. This is understandable since this compound has not been used as a substitute to ozone depleting substances.

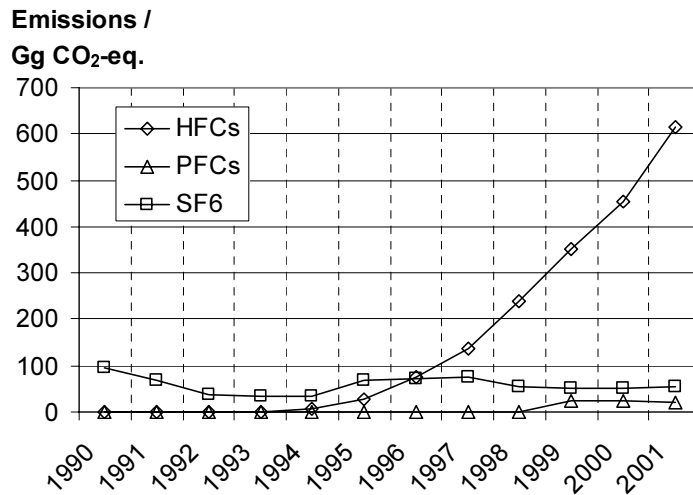


Figure 3.8-1: Change in emissions of HFCs, PFCs and SF₆ over time.

3.9 Review findings

This section explains how the findings of the individual reviews of the Finnish inventory were included in the work to improve the inventory. There are currently two published review reports for the two types of individual reviews conducted. The results of a desk review were published as document FCCC/WEB/IRI(1)/2001/FIN and the results of an in-country review as document FCCC/WEB/IRI(2)/2001/FIN.

The in-country review report identifies transparency as an area of further improvement. This issue is addressed by the report at hand, by explaining the reasons of confidentiality and how it is treated in the inventory (section 2.7, p. 18) and sections under 2.4 Choice of emission models. Moreover, an attempt has been made to report as much of the background information as possible, while trying to safeguard confidential data.

The desk review report recommends that potential to actual SF₆ emissions ratios should be checked to make sure that they have been reported accurately. These were checked for each year and errors corrected. The results are shown in Figure 3.9-1. Now the ratio is higher than one for each year, indicating that potential emissions are greater than actual, as should be the case in most situations.

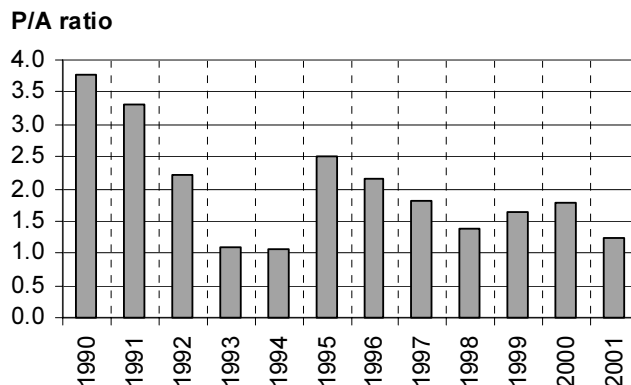


Figure 3.9-1: Potential to actual emissions ratios for SF₆ emissions.

3.10 Recalculation

3.10.1 HFC, PFC and SF₆ emissions from semiconductor manufacturing

In 2002, a group of HFC, PFC and SF₆ end-users were surveyed for their gas consumption in manufacturing semiconductors. The group consisted of companies, research institutes and universities. It turned out that of 12 potential users surveyed, only 4 had actually consumed these substances. Two of the potential users did not respond despite the fact that several contacts were made via postal mail, e-mail and telephone.

The survey nevertheless yielded a picture that is more reliable than previous ones. First of all, gas consumption by species was obtained from those that know the use of the substance. Second, the 2002 survey of end-users yielded estimates of actual consumption (because the users' consumption level is very low, the quantity of gases sold during a given year may actually be consumed over a number of years).

Confidentiality of the activity data makes it difficult to document the recalculation in a fully transparent way. A very simple model to recalculate the inventory was used:

$$E_t = E_{2001} (1 + 0.15)^{-(2001-t)}$$

This model assumes an annual growth of emissions of 15% for the period 1990–2000. The use of 15% reflects the general growth of production within the industry (Oinonen & Soimakallio 2001), but may not be an appropriate indicator for growth of emissions because of rapid changes in production technology and gases used. The associated uncertainties are tolerable, however, given the very low contribution of this emission source to overall emissions.

The recalculated emissions were reported in an aggregated form with other grouped estimates.

3.10.2 SF₆ emissions from electrical equipment

Application of the emission factor method discussed in section 2.4.2 gives 19 Gg CO₂-equivalent for year 2001, which is 53% of the estimate in Table 3.1-2 (p. 20). The difference may partly be attributed to the fact that previous calculations assumed zero emissions from decommissioning. The new method calculates decommissioned quantities based on assumptions regarding equipment lifetime and growth in annually installed new nameplate capacity (cf. section 2.4.2 p. 8). It is also possible that the emissions factors used may have been too low, or alternatively, that the activity data to which the factors have been applied have been too low. Of course, all of these three factors may have occurred simultaneously in varying degrees.

Previous estimates were recalculated using overlapping data for 2001, i.e. by multiplying actual emissions estimates for 1990–2000 by 1.89 (36 Gg CO₂-eq/19 Gg CO₂-eq.).

3.10.3 HFCs from fixed fire fighting systems

Emissions from fixed fire fighting systems were recalculated due to availability of improved data; please see section 2.4.8 (p. 14).

3.10.4 SF₆ from shoes

SF₆ emissions from shoes were added to the inventory as a new source.

3.10.5 Changes in emission estimates following from recalculation

Following recalculation, emissions of HFCs and PFCs generally decreased whereas SF₆ emissions increased. Total F-gases estimates for 1990–2000 increased by 30% on average. In absolute terms the change ranged from 5 to 60 Gg CO₂-eq. The differences between previous and latest estimates are depicted in Figure 3.10-1. Compared to the overall level of greenhouse gas emissions, the maximum change following from recalculation was 0.07%.

Recalculation affected estimates of annual emissions differently. The change was smaller in years 1998–2000, because the level of emissions during those years was considerably higher compared to the previous years. On the other hand, in 1995, the fairly large change in estimate, combined with a low level of emissions, caused the estimate to double due to recalculation.

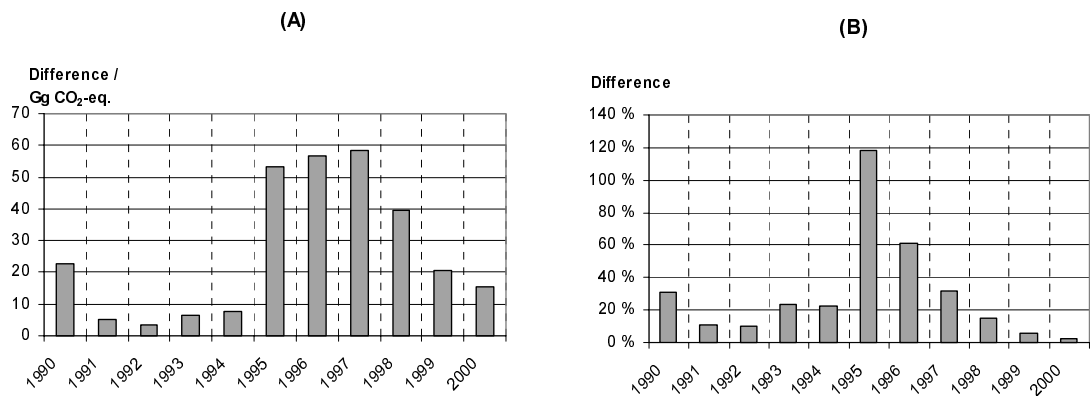


Figure 3.10-1: Differences between previous and latest submissions following from recalculation. Differences are shown for each inventory year both in absolute (A) and proportional (B) terms.

4 CONCLUSIONS

In 2001, Finnish overall emissions of F-gases amounted to 0.7 million metric tons of carbon dioxide equivalent. Potential emissions were approximately two-fold totaling 1.3 Mt CO₂-eq. Emissions increased by 27% from previous year, and were roughly eight-fold compared to emissions in 1990. Emissions of HFCs, PFCs and SF₆ made thus 0.9% of the total greenhouse gas emissions in 2001. Most of the growth in emissions of HFCs and PFCs has occurred due to their increased use as refrigerants and propellants, where they have replaced most of the previous use of ozone depleting CFCs and HCFCs.

Most of the F-gas emissions (75%) originated from refrigeration and air conditioning. Emissions from aerosols, one-component polyurethane foam cans, foam blowing and electrical equipment contributed 22% of the emissions. An aggregated estimate for confidential emissions data—magnesium die-casting, running shoes, fixed fire fighting equipment, HFC-23 from refrigeration and air conditioning, and semiconductor manufacturing—amounted to some 3% of total F-gases emissions.

In the 2001 inventory, uncertainties in the estimates were quantified for the first time. Expressed as 95% confidence intervals, actual emissions were between 0.4 and 0.8 Mt CO₂-eq. The high uncertainty originate in most part from the uncertainty in the estimate for refrigeration and air conditioning source category. This in turn is due to non-coverage of the survey with respect to companies operating in the industry. Although the survey covered 185 companies, the total amount of companies is much higher, approximately 850. The uncertainty is expected to become considerably smaller in the inventory for 2002 as a list of contact details for these companies became available in 2002.

The completeness of the inventory was improved by addition of a new source (SF₆ emissions from shoes). Due to this addition, recalculation of the inventory was necessary. Changes were also made in models used to calculate emissions from electrical equipment, and better activity data was gathered for semiconductor manufacturing and fixed fire fighting systems. All of these sources were recalculated due to the changes made.

As a response to the desk and in-country review findings, the documentation of the inventory was improved, especially with respect to treatment of confidential data. Mistakes resulting in incorrect potential to actual emission ratios for SF₆ were also corrected.

Efforts to improve the F-gases inventory should concentrate on the further development of the quality assurance and quality control system.

REFERENCES

- Anon. (1997):** *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Reference Manual*. The publication is electronically available at <http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm>.
- Bartos, Scott & Burton, C. Shepherd (2000):** Chapter 3.6 in Penman (2000), *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, pp. 3.69–3.78.
- Council Decision 1999/296/EC:** Council Decision of 26 April 1999 amending Decision 93/389/EEC for a monitoring mechanism of Community CO₂ and other greenhouse gas emissions, *Official Journal of the European Communities L 117/35*, 5.5.1999. The decision is available electronically at <http://europa.eu.int/eur-lex>.
- FCCC/CP/1999/7:** UNFCCC guidelines on reporting and review, 16.2.2000. The guidelines are available electronically at <http://unfccc.int>. A decision to replace these guidelines by a new one was taken by the Conference of the Parties in New Delhi 2002. At the time of writing, these new guidelines are available as unedited advance versions: please see <http://unfccc.int/cop8/index.html>.
- FCCC/WEB/IRI(1)/2001/FIN:** Report of the Individual Review of the Greenhouse Gas Inventory of Finland Submitted in the Year 2001 (Desk Review). The report is available electronically at <http://unfccc.int/program/mis/ghg/indrev2001.html>.
- FCCC/WEB/IRI(2)/2001/FIN:** Report of the Individual Review of the Greenhouse Gas Inventory of Finland Submitted in the Year 2001 (In-Country Review). The report is available electronically at <http://unfccc.int/program/mis/ghg/indrev2001.html>.
- Forte, Reynaldo, Jr., McCulloch, Archie & Midgley, Pauline (2000):** Chapter 3.7 in Penman (2000), *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, pp. 3.79–3.122.
- Galbally, Ian, Paciornik, Newton & Tichy, Milos (2000):** Annex 1 in Penman (2000), *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, pp. A1.1–A1.22.
- Gamlén, P. H., Lane, B. C., Midgley, P. M. & J. M. Steed (1986):** "The production and release to the atmosphere of CCl₃F and CCl₂F₂ (chlorofluorocarbons CFC 11 and CFC 12)", *Atmospheric Environment*, Vol 20, No. 6, pp. 1077–1085.
- Government decree 1187/2001:** Government decree on servicing and qualifications of service and waste management personnel of equipment containing ozone depleting substances and certain hydrofluorocarbons (in Finnish), published in *Suomen säädöskokoelma*, 12.12.2001 Helsinki.
- Heikkilä, Erkki (2002):** personal communication with Erkki Heikkilä of Sprinklerhuset Finland Oy, 28.8.2002.
- Lemmetti, Marjukka (2002):** personal communication with Marjukka Lemmetti of Alteams Oy, 4.10.2002.
- Oinonen, Teemu (2002):** *Good practice guidance to companies* (In Finnish), Finnish Environment Institute, unpublished manuscript, 11.7.2002.
- Oinonen, Teemu (2000):** *Sources, Emissions and Potential Emission Reduction Options of Hydrofluorocarbons, Perfluorocarbons and Sulphur Hexafluoride in Finland*, Finnish Environment Institute, unpublished manuscript, April 2000.
- Oinonen, Teemu & Soimakallio, Sampo (2001):** *Technical and economic evaluation of emission abatement options of HFCs, PFCs and SF₆. The case of Finland* (In Finnish, abstract in English), VTT Research Notes 2099, Technical Research Centre of Finland, Espoo.

- Olivier, Jos & Bakker, Joost 2000:** Chapter 3.5 in Penman (2000), *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, pp. 3.53–3.68.
- Palmer, Bill (2000):** Chapter 3.4 in Penman (2000), *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, pp. 3.48–3.52.
- Penman, Jim (2000):** *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*. The publication is electronically available at <http://www.ipcc-nggip.iges.or.jp/public/gp/gpgaum.htm>.

APPENDIX 1

The following table provides links between the Common Reporting Format tables, and sections of this report. A summary of models used to calculate emissions is presented in Table 2.4-3, p. 14.

Table in CRF	Emission models	Results	Notes regarding reporting using CRF
Table2(I)s2 (Sectoral report for industrial processes: summary of potential and actual emissions for HFCs, PFCs and SF ₆ by source)	For methods used, please see below.	Summaries of emissions by source, section 3.6 p. 25.	The total F-gases emission figures in this table contain also data that has been grouped to minimize the risk of releasing confidential information. The treatment of confidentiality issues is described in section 2.7 p. 18.
Table2(II).Fs1 (Background data for actual emission estimates: refrigeration and air conditioning source categories)	Refrigeration and air conditioning, section 2.4.5 p. 10. Foam blowing, section 2.4.7 p. 12.	Refrigeration and air conditioning, section 3.2 p. 20. Foam blowing, section 3.4 p. 24.	IEs ('included elsewhere') indicate that emissions from all RAC sub-categories are reported as aggregated figures under 'commercial refrigeration'. The CRF is not well suited for reporting results calculated with the top-down model, resulting in NAs ('not applicable') shown in this table. Confidential estimates marked with C are reported as aggregated figures. The grouped data have been added to the carbon dioxide equivalent (CO ₂ -eq.) emission estimates in Table2(I)s2.
Table2(II).Fs2 (Background data for actual F-gases emission estimates: rest of the consumption related source categories)	Fire extinguishers, section 2.4.8 p. 14. Aerosols, section 2.4.6 p. 11. Semiconductors, section 2.4.4 p. 9. Electrical equipment, section 2.4.2 p. 8.	Fire extinguishers, section 3.5 p. 24. Aerosols, section 3.3 p. 23. Semiconductors, section 3.5 p. 24. Electrical equipment, section 3.1 p. 20.	Cs and NAs are used as explained above. Also, due to confidentiality, emissions from MDIs and other aerosols are not reported separately.
Table2(II).C,E (Background data for metal production and production of halo-carbons and SF ₆)	Magnesium die casting, section 2.4.1 p. 7.	Magnesium die-casting, section 3.5 p. 24.	In case of Finland, magnesium die-casting is the only relevant source category of this table. The data for the source are confidential and reported in the grouped data.
Table2(II)s1 (Sectoral report—total actual emissions)	Methodologies as given above	See notes.	Results reported by species and by source are confidential in many cases.
Table2(II)s2 (Sectoral report—total potential emissions, and potential-actual comparison)	Methodologies as given above for actual emissions. For potential emissions, the methodology is described in Anon. 1997 pp. 2.47–2.50.	See notes.	Results reported by species and by source are confidential in many cases. Grouped data have been edited to formulas is specific cells of the table, so that potential-actual comparison is facilitated and that sums of emissions are correct.

Table in CRF	Emission models	Results	Notes regarding reporting using CRF
Summary1.As1 (Summary of total national emissions)	As given above.	See summary of emissions by source, section 3.6 p. 25.	
Summary1.B (Short summary of total national emissions)	As given above.	See summary of emissions by source, section 3.6 p. 25.	
Summary2 (Summary showing total emissions in CO ₂ equivalents)	As given above.	See summaries by source and by gas, sections 3.6 p. 25.	
Summary 3s1 (Summary for methods used)	See notes.	See notes.	This information can be found in Table 2.4-3 p. 14 of this report.
Table7s1 (Completeness and qualitative estimates of uncertainty—actual F-gases emissions)	See notes.	See notes.	Completeness of the inventory is discussed in section 2.1 p. 6, and uncertainty analysis is described in section 2.2 p. 7. A straightforward derivation of statements regarding quality from quantitative uncertainty results is not possible. A subjective assessment of quality ranks was used to fill this table.
Table7s2 (Completeness and qualitative estimates of uncertainty—potential F-gases emissions)	See notes.	See notes.	Completeness of the inventory is discussed in section 2.2 p. 6, and uncertainty analysis is described in section 2.3 p. 7. A straightforward derivation of statements regarding quality from quantitative uncertainty results is not possible. A subjective assessment of quality ranks was used to fill this table.
Table10s4 (F-gases emission trends by gas)	As given above.	See section 3.8 p. 28.	The detailed disaggregation of individual chemical species is not reproduced in this report.
Table10s5 (Emission trends in CO ₂ equivalents)	As given above.	See section 3.8 p. 28.	A detailed discussion on emission trends in different sectors is given in section 3.7 p. 26.

DOCUMENTATION PAGE

Publisher	Finnish Environment Institute	Date June 2003
Author(s)	Teemu Oinonen	
Title of publication	Finnish 2001 inventory of HFC, PFC and SF ₆ emissions	
Parts of publication/ other project publications	This publication is available on the Internet at http://www.ymparisto.fi/julkaisut	
Abstract	<p>This report documents the Finnish inventory of HFC, PFC and SF₆ emissions in 2001. It aims to fulfil the reporting requirements laid down within the United Nations Framework Convention on Climate Change. The emphasis is placed on explaining what methods and data was used in preparation of the inventory.</p> <p>The report describes the sources included in the inventory as well as sources excluded, giving an overall view of the completeness of the F-gases reporting. Following that, models used to calculate emissions and uncertainties are explained; the aim is to show that accuracy of estimates was one of the key considerations in preparing the inventory. Results of the inventory, as well as recalculation and responses to inventory reviews, are presented before turning to conclusions and recommendations for future work. The document also contains a table that provides linkages between the Common Reporting Format used to report emissions and the relevant sections of the document. It is hoped that the information provided facilitates the assessment of consistency, comparability and transparency of the inventory.</p> <p>In 2001, emissions of HFCs, PFCs and SF₆ continued to increase. The level of emissions was 0.7 Mt CO₂-eq. with a 95% certainty range from 0.4 to 0.8 Mt CO₂-eq. The contribution of F-gases to total Finnish emissions of greenhouse gases was thus 0.9%.</p>	
Keywords	F-gases, HFC-compounds, PFC-compounds, sulphur hexafluoride, inventories, climate change, international conventions, United Nations, greenhouse gases, emissions, Finland	
Publication series and number	Suomen ympäristökeskuksen moniste 278	
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KUVAILOLEHTI

Julkaisija	Suomen ympäristökeskus	Julkaisu-aika kesäkuu 2003
Tekijä(t)	Teemu Oinonen	
Julkaisun nimi	Finnish 2001 inventory of HFC, PFC and SF ₆ emissions (F-kaasujen vuotuinen päästöinventointi)	
Julkaisun osat/ muut saman projektin tuottamat julkaisut	Julkaisu on ladattavissa sähköisesti Internetissä osoitteessa http://www.ymparisto.fi/julkaisut	
Tiivistelmä	<p>Tämä raportti kertoo kuinka F-kaasujen päästöinventointi vuodelle 2001 laadittiin. Tavoitteena on täyttää YK:n ilmastopöytäkirjan päästöjen raportoinnille asettamat vaatimukset. Raportin pääpaino on niiden menetelmien ja lähtötietojen kuvaamisessa joita inventointiin valmistelussa käytettiin.</p> <p>Raportti pyrkii kuvaamaan raportoinnin kattavuuden (mitkä päästölähteet ovat mukana, mitkä taas jätetty pois). Raportissa osoitetaan myös päästöjen ja epävarmuuksien laskennassa käytettyjen mallien kuvauksin, että eräs työtä keskeisesti ohjaava periaate oli pyrkimys mahdollisimman tarkkaan tietoon päästöistä. Tekstissä esitetään myös inventointitulokset, kuvataan tehty uudelleenlaskenta, ja vastataan inventointitulosten tarkastuksissa tehtyihin huomioihin. Lopuksi esitetään johtopäätökset ja suositukset. Raportti sisältää myös taulukon, joka helpottaa yhteyksien löytämistä kasvihuonekaasupäästöjen raportoinnissa käytetyn Common Reporting Formatin ja tämän raportin osioiden välillä. Tavoitteena on ollut, että raportin avulla voidaan arvioida inventointijohdon mukaisuus, vertailtavuus ja läpinäkyvyys.</p> <p>Suomen F-kaasujen päästöt kasvoivat edelleen vuonna 2001. Päästöjen taso oli 0,7 Mt CO₂-ekv., ja sille arvioitu 95 %:n luottamusväli 0,4...0,8 Mt CO₂-ekv. F-kaasujen osuus Suomen kaikkien kasvihuonekaasujen päästöistä oli siten 0,9 %.</p>	
Asiasanat	F-kaasut, HFC-yhdisteet, PFC-yhdisteet, rikkiheksafluoridi, inventointi, ilmastomuutokset, kansainväliset sopimukset, YK, kasvihuonekaasut, päästöt, Suomi	
Julkaisusarjan nimi ja numero	Suomen ympäristökeskuksen moniste 278	
Julkaisun tema		
Projektin nimen ja projektinumeron	F-kaasujen vuotuinen päästölaskenta ja sen kehittäminen (VC05020)	
Rahoittaja/toimeksiantaja	Ympäristöministeriö	
Projektiryhmään kuuluvat organisaatiot		
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Painopaikka ja -aika	Helsinki 2003	
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