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Emissions and Emission Projections of HFC, PFC and SF_6 in Germany – Present State and Development of a Monitoring System

Emissions 1990, 1999-2003, and
Emission Forecasts for 2010 and 2020

by

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16. Abstract

The Framework Convention on Climate Change and its follow-up regulations include special commitments on transmission of emissions data as well as the data basis (activity data) and the applied methodologies. National emissions reporting on the fluorinated greenhouse gases HFCs, PFCs, and SF_6 requires establishing
- Emissions of HFCs, PFCs (about 20 individual fluids), and SF_6 in metric tonnes and CO_2 equivalents from industrial processes, by individual sectors,
- Emission Projections of HFCs, PFCs and SF_6 in Germany,
- Rating of the effects of implemented and intended emission reduction measures.

In this context the following report was prepared. It consists of three parts.

Part I presents a proposal for a future national F-gas monitoring system designed to provide equal quality of activity data and emission factors with less expenditure. Its main features are higher efficiency, institutionalisation, and enhancement of data quality. This can be achieved by making differentiated precision demands on emission sources within "key emission sources" and, additionally, by using the new Environmental Statistics Law as well as database systems for refrigerant management being under way now. The new monitoring system is explained sector by sector.

Part II contains both emission data for the years 1999 to 2003 as required for Germany's emissions reporting on F-gases, and emission forecasts for 2010 and 2020. The latter are each based on four different scenarios one of which considers the emission reduction effect of the forthcoming EC Regulation on Certain Fluorinated Greenhouse Gases and EC Directive on HFC-134a Phase-out from Passenger Car Air Conditioners.

Part III provides historic emission data for the year 1990. Their retroactive estimation and documentation is necessary to meet the completeness criterion set out by UNFCCC for national emissions reporting. Due to the extremely high GWP of the then emitting F-gases SF_6, HFC-23, and CF_4, the 1990 emission level was not very far below that of the year 2003 which is characterised by the new and deliberately produced HFCs.

17. Keywords

Fluorinated Greenhouse Gases; Emissions; Emission Forecast, Reporting; CRF, ZSE; Activity data; Emission factors; Hydrofluorocarbons (HFCs); Perfluorocarbons (PFCs); Sulphur Hexafluoride (SF_6)

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16. Kurzfassung

Die Klimarahmenkonvention (UNFCCC) und ihre Folgeregelungen enthalten konkrete Verpflichtungen zur Übermittlung klimawirksamer Emissionen, einschließlich der zu ihrer Ermittlung verwendeten Basisdaten (Aktivitätsdaten) und Erhebungs- und Berechnungsmethoden. In Bezug auf die fluorierten Klimagase HFKW, FKW und SF_6 sind für die nationale Emissionsberichterstattung zu ermitteln:

- Emissionen von HFKW, FKW (ca. 20 Einzelstoffe) und SF_6 in Tonnen und CO_2-Äquivalenten aus industriellen Prozessen, aufgegliedert nach Sektoren.
- Emissionsprognosen für HFKW, FKW und SF_6 .
- Umgesetzte und geplante Maßnahmen zur Emissionsreduktion und sich daraus ergebende Effekte.

Dieser Forschungsbericht entstand in diesem Zusammenhang. Er besteht aus drei Teilen.

Teil I präsentiert einen Vorschlag für das künftige nationale F-Gas-Monitoring-System, der gleiche Datenqualität (Aktivitätsdaten und Emissionsfaktoren) mit weniger Aufwand erzielen soll. Seine Grundzüge – Straffung, Institutionalisierung, Hebung der Datenqualität – sind erstens durch abgestufte Präzisionsanforderungen bei Emissionsquellen innerhalb von "Hauptquellgruppen" und zweitens durch Nutzung des neuen Umweltstatistikgesetzes und neuer Datenbanksysteme für Kältemittel gegeben. Das neue Monitoringsystem wird Sektor für Sektor erläutert.

Teil II zeigt die für die Emissionsberichterstattung erforderlichen jährlichen Emissionen fluorierter Treibhausgase für die Jahre 1999 bis 2003. Er enthält außerdem Emissionsprognosen für die Jahre 2010 und 2020 nach vier verschiedenen Szenarien, von denen dasjenige sicher das wichtigste ist, das die Wirkung der geplanten EU-Verordnung über bestimmte fluorierte Treibhausgase und der EU-Richtlinie zum HFKW-134a-Ausstieg bei Kfz-Klimaanlagen enthält.

Teil III enthält historische Emissionsdaten des Jahres 1990. Deren rückwirkende Abschätzung und Dokumentation ist für die Konsistenz der Emissionsberichterstattung nach UNFCCC erforderlich. Aufgrund des extrem hohen GWP der emittierenden F-Gase SF_6, HFKW-23 und CF_4 lag das Emissionsniveau damals nur wenig unter dem des Jahres 2003, das durch neue HFKW geprägt ist.

17. Schlagwörter

Fluorierte Treibhausgase; Monitoring, Emissionsprognose, Emissionen, F-Gase; Berichterstattung; CRF, ZSE; Aktivitätsdaten; Emissionsfaktoren; HFKW, FKW; SF_6 ; UNFCCC;

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Contents

Summary

The United Nations Framework Convention on Climate Change and its follow-up regulations include special commitments on transmission of emission data as well as the data basis (activity data) and applied methodologies. In connection with the international agreements on climate protection, information on emissions have also to be reported to the European Commission. National emissions reporting on the fluorinated greenhouse gases HFCs, PFCs, and SF_6 requires establishing

- Emissions of HFCs, PFCs (about 20 individual fluids), and SF_6 in metric tonnes and CO_2 equivalents from industrial processes, by individual sectors,
- Emissions projections of HFCs, PFCs and SF_6 in Germany,
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Author of this report including its translation into English is Winfried Schwarz. Sina Wartmann contributed a good deal to Part I including translation.

Frankfurt am Main, 31 October, 2005

Part I
The New F-Gas Monitoring System

Objective: Equal Data Quality at Less Expenditure

The annual emission inventory of fluorinated Greenhouse Gases pursuant to the Common Reporting Format (CRF) according to UNFCCC has so far been compiled by Öko-Recherche, who collects all data and prepares them for entering into the "Centralised System Emissions" (ZSE) data base at the Federal Environmental Agency (UBA). Methods used follow two basic studies:

- Schwarz, W. /Leisewitz, A.: Present and Future Emissions of fluorinated Greenhouse Gases in Germany, on behalf of the UBA, Berlin, December 1996.
- Schwarz, W. /Leisewitz, A.: Emissions and Emission Reduction Potentials of HFCs, PFCs and SF_6 in Germany, on behalf of the UBA, Berlin, October 1999.

Since 1999, emission relevant data is collected for forty industry sectors mainly through own surveys, through interviews with manufacturers, users, dealers, trade associations, and further sector experts. In particular cases Öko-Recherche makes use of data reported in the frame of sector-specific voluntary commitments. The system of data collection is described in detail in UBA-Text 15/05[1].

It is an objective of this project to render the F-gas monitoring system less dependent from numerous personal contacts of Öko-Recherche. In order to do so, possibilities of direct reporting to Federal Environmental Agency by companies and associations on a voluntary but binding basis were to be explored. The main point, however, was the elaboration of proposals for a system of surveying emissions that manages to fulfil international reporting obligations at less expenditure of labour and time, with the quality of emission data remaining at the same or even at a higher level.

The ZSE has recently become the national database for calculation and reporting of emissions. It automates numerous working steps, once the activity data of previous reporting years have been entered as time series together with the respective emission factors. The ZSE significantly reduces the expenditure connected with the reporting process as a whole. Nevertheless, the annual sub-process of collecting new data to enter into ZSE requires the same amount of work as before.

The proposals for a modern and less time-consuming monitoring system take into consideration the general framework given by the UNFCCC reporting guidelines as reporting demands on the one hand and by the "tools" already existing or being under way at national level, on the other hand. In this context, the possibility of employing the Environmental Statistics Law (UStatG) for data collection should be explored, and it ought to be tried to make it more useful for the F-gas inventory through personal participation in its present amending process.

Reforms presented here in part I may be characterised by the following key terms:

1. **Efficiency,**
2. **Institutionalisation,**
3. **Enhancement in data quality.**

[1] Winfried Schwarz: Emissions, Activity Data, and Emission Factors of Fluorinated Greenhouse Gases (F-Gases) in Germany 1995-2002 - Adaptation to the Requirements of International Reporting und Implementation of Data into the Centralised System of Emissions (ZSE), Dessau, June 2005, UBA-Text 15/05, http://www.umweltbundesamt.org/fpdf-l/2903.pdf.

To 1. Efficiency

Data collection can be greatly simplified by defining differentiated precision demands on the individual sources of emission (sectors), for the first time. So far the attempt has been made to achieve the highest possible degree of detail for all sources. The Federal Environmental Agency has recently taken the position that the most rigorous methods, which is to say at least "tier 2" according to IPCC-Good Practice Guidance 2000, need to be applied only to two thirds of emissions of "key-sources", to which all F-Gas sectors belong. This position allows using less rigorous data estimates in smaller sectors. After almost ten years of complete direct surveys, now in many cases rough estimates based on trend extrapolation suffice to yield appropriate data quality. Intervals between direct emissions surveys can be increased up to several years, in individual cases direct emissions determination can even cease.

To 2. Institutionalisation

Up to now, three sector associations have entered into voluntary commitments that include emission reduction targets as well as annual monitoring and reporting of emissions to the Federal Environmental Agency. Such commitments exist in primary aluminium industry (PFCs), in manufacture and use of equipment for power transmission and –distribution (SF_6), and in semiconductor industry (PFCs, SF_6, and HFCs). Self-commitments of this kind make data collection independent from personal contacts, and thus more reliable and binding over the long term. Further voluntary commitments with reduction targets are not to be expected for the near future. Nevertheless nearly all associations and major companies interviewed in the course of this study declared at least their willingness to sign limited written agreements with the Federal Environmental Agency on annual direct reporting of emissions to this Agency (or of activity data allowing the calculation of emissions).

To 3. Enhanced data quality

The Environmental Statistics Law (UStatG), which has conducted annual data surveys on domestic use of HFCs and PFCs since 1997, has not yet been deployed for emissions determination so far, although the surveys address 8,000 companies annually. This is mainly because the industrial sectors (”Wirtschaftszweige") the UStatG addresses were incompatible with the monitoring structure according to CRF ("sources"). During the preparation of the new UStatG important adjustments could be proposed (e.g. in propellants for aerosols and blowing agents for foams). Furthermore, SF_6 was included in data collection according to amended UStatG. Now, the UStatG can yield activity data and partly even emissions for several sources in line with CRF reporting demands. Data that has been collected through other channels so far can either now be substituted by more accurate data or can be crosschecked with the UStatG results.

At present two databank-based systems that are potentially suited to deliver data on refrigerants for the national F-gas inventory are under way: EcoKlima and VDKF-LEC. As soon as a sufficiently large number of air conditioning and refrigeration systems is entered into the databases by types as well as initial and service fills of refrigerants, emissions of complete source categories like commercial refrigeration, industrial refrigeration, transport refrigeration, stationary air-conditioning, can be mapped. At present, these large F-gas sectors show a rather low level of data accuracy and certainty. In the medium term significant enhancement in data quality is to be expected, as a start for the emission factors currently available in ZSE.

First Chapter
Main Features of the New Monitoring System

In this chapter, each of the three main characteristics of the new monitoring system will be addressed individually in the following order:

(I) Higher efficiency through differentiated demands on data accuracy,
(II) Institutionalisation through direct reporting agreements to the UBA,
(III) Enhanced data quality by means of new UStatG and new database-systems for refrigerant management.

Afterwards, in the second chapter, the future monitoring system will be presented sector-by-sector for all F-gas sources.

I. Higher efficiency through differentiated precision demands

Prior to data collection, the methods and thus the degree of detail of emission modelling and calculation have to be decided. The level of detail depends on the classification of emission sources as "key-sources" or not. The term "data" includes according to QAE (Quality Assurance Emissions) manual numerical values such as activity data, emission factors, statistical uncertainties as well as e.g. documentation texts to be entered into the national inventory report.

1. The three F-gas key-sources and their subdivision

According to the classification pursuant to CRF three F-gas source-groups exist: (1) Metal Production (2.C), (2) Production of Halocarbons and SF_6 (2.E), and (3) Consumption of F-Gases (2.F). Key-sources are not only defined by their absolute level of emissions. A key-source is a "highlighted" source in the national inventory, whose emissions have a significant impact on the total GHG-emissions – either on their level or their trend. The latter criterion means fast changes (increase or reduction) of emissions. As per Table 1 this criterion is met by all the three CRF F-gas source-groups:

Table 1: F-gas source-groups, by level of global warming emissions 2003, and by emission trend since 1995		
Sources according to CRF	Emissions in kt CO_2 equivalent 2003	Emissions 2003 vs. 1995 in %
2. C Metal production	2007	+ 15%
2. E Production of halocarbons	772	- 82%
2. F Consumption of halocarbons	10911	+ 17%
- thereof SF_6	*2607*	*- 62%*
- thereof FKW	*381*	*+ 93%*
- thereof HFKW	*7893*	*+ 248%*
All sources	13690	- 12%

Source: Annex to Part II of this study.

Table 1 shows the fast up and down fluctuations of emissions in the three main F-gas sources. Within eight years, emissions of source 2.C rose by 15% and of source 2.F by 17%, while emissions of the source 2.E (owing to the reduction in HFC-23 emissions from HCFC-22 production) fell by 82%. The 17% increase of emissions from source 2.F (Consumption) includes both upwards and downwards trends: HFCs increased by 248%, PFCs by 93%, while SF_6 emissions decreased by 62%.

Following the definition of the term "key source", which the Federal Environmental Agency agrees to, all the tree main F-gas sources are key-sources. This is of high importance, as the highest level of data quality ("tier") presented in the currently valid IPCC guidelines (IPCC GL 2000) must be adopted for these sources.

2. The "two-thirds" emission threshold

The basic criterion named above must be applied in conjunction with other factors. According to the current interpretation of the international specifications by the Federal Environmental Agency "at each hierarchy level, in a key-source at least tier 2 or a comparable and nationally documented approach has to be applied – to those sub sources which jointly contribute two thirds to its total emissions." (Letter from Michael Strogies, dated 29.06.2005). In other words, in each of the three key-sources 2.C, 2.E, 2.F a high degree of data precision (usually tier 2) must be implemented in at least two thirds of the emissions determined in 2003 (the most recent reporting year). Conversely, that means this requirement does not need to be applied to sub sources whose emissions cumulate to the remaining one third of the key-source emissions. For these sources less detailed tier approaches such as rough expert estimates or trend extrapolations are deemed sufficient in emissions estimation.

Table 2 on the next page compiles all emission sources that have been determined by CRF hierarchy levels as of 1995. The absolute and percentage values in this Table make it possible to attribute to each individual sector (source) the appropriate precision of data collection.

The first column of Table 2 lists all emission sources, i.e. the three key-sources, their sub sources of 1st and of 2nd order which are prescribed by CRF, as well as individual sources at the lowest level (sub sources of 3rd order) that have been determined without CRF specification in the past (italics).

The second column contains the respective 2003 emissions in kt CO_2-equivalent.

The third column shows the percentage share of each individual [sub] source in the emissions of the key-source it belongs to (defined as 100%).

In the fourth column only key-source 2.F (Consumption) is presented. It is broken down into its three largest first order sub sources "Refrigeration and Air-Conditioning”, "Foam Blowing”, and "Other SF_6 Applications” in order to determine the emission proportions of their sub sources in relation their own subtotal emissions. (This is the reason why the percentages in the fourth column are higher than in the third column, where they relate to the total of emissions from the F-gas consumption key-source.)

Tab. 2: Key-sources and different-level sub sources of F-gas emissions in Germany 2003, in kt CO_2 equivalent – acc. to CRF			
Key- and Sub Sources of diff. Order	**kt CO_2 eq.**	**% of key source**	**% of sub source**
2.C PFCs and SF_6 from Metal prod.	2007	**=100%**	
SF_6 (and HFC-134a)	1532	76%	
Magnesium Foundries SF_6	*457*	*23%*	
Magnesium Foundries HFC-134a	*0,3*	*0,01%*	
Aluminium Foundries SF_6	*1075*	*54%*	
PFCs from Aluminium Production	475	24%	
2.E Production of Halocarbons and SF_6	772	**=100%**	
1. By-product Emissions HFC-23	Confidential	Confidential	
2. Fugitive Emissions	Confidential	Confidential	
HFC-134a	Confidential	Confidential	
HFC-227ea	Confidential	Confidential	
SF_6	Confidential	Confidential	
2.F Consumption of Halocarbons and SF_6	10911	**=100%**	
1. Refrigeration and Air Conditioning	5886	53,9%	**=100%**
Domestic Refrigeration	2	0,02%	0,03%
Commercial Refrigeration	2391	21,9%	40,6%
Transport Refrigeration	208	1,9%	3,5%
Refrigerated vehicles	*167*	*1,5%*	*2,8%*
Refrigerated containers	*40*	*0,4%*	*0,7%*
Industrial Refrigeration	705	6,5%	12,0%
Stationary Air-Conditioning +	219	2,0%	3,7%
Centralized AC systems	*186*	*1,7%*	*3,2%*
Room Air Conditioners	*28*	*0,3%*	*0,5%*
Heat pumps	*5*	*0,04%*	*0,1%*
Mobile Air-Conditioning	2362	21,6%	40,1%
Passenger Cars	*2101*	*19,3%*	*35,7%*
Trucks	*91*	*0,8%*	*1,6%*
Buses	*91*	*0,8%*	*1,5%*
Agricultural machines	*45*	*0,4%*	*0,8%*
Ships	*2*	*0,02%*	*0,03%*
Railcars	*32*	*0,3%*	*0,5%*
2. Foam Blowing (Rigid foam)	1442	13%	**=100%**
XPS	698	6,4%	*48,4%*
OCF	587	5,4%	*40,7%*
Integral skin	113	1,0%	*7,8%*
Other PU rigid foam	45	0,4%	*3,1%*
3. Fire Extinguishers	6	0,05%	
4. Aerosols/Metered Dose Inhalers	655	6%	
MDI	*318*	*2,9%*	
Techn. Aerosols	*213*	*1,9%*	
Novelties	*124*	*1,1%*	
5. Solvents	1,9	0,02%	
6. Semiconductor Manufacture	351	3,2%	
7. Electrical Equipment	629	5,8%	
8. Other SF_6 applications	1940	17,8%	**=100%**
Car tires	*143*	*1,3%*	*7,4%*
Soundproof glazing	*1155*	*10,6%*	*59,6%*
Military Radar+Shoe soles	*273*	*2,5%*	*14,1%*
Glass fibres	*96*	*0,9%*	*4,9%*
Particle accelerators	*117*	*1,1%*	*6,0%*
Capacitors	*143,4*	*1,3%*	*7,4%*
Tracer gas	*13*	*0,1%*	*0,6%*

Explanation: Letters (C, E, F) refer to key-sources. Numbers (1-8), grey-shaded, refer to 1st order sub sources of key-sources as per CRF. No numbering, no shading, normal fonts indicate 2nd order sub sources (partial sources of 1st order sub sources). Indented, italics, and no numbering, means lowest level sources (3rd order sub sources).

3. Sub sources with high precision in data collection

1. Emissions from magnesium die-casting (SF_6 and HFC-134a) contribute only 23% to F-gas emissions from key-source "Metal Production" (2.C). In this case highest precision in data collection is not required according to the cumulative "two thirds" emission threshold. As currently HFC-134a is substituting SF_6 in this application, a strong increase in HFC emissions is to be expected. Therefore it is recommended to treat this source like the others, the more so as discrete expenditure on data collection in this source will be reduced in the future in consequence of the amended Environmental Statistics Law.

2. Applying the "two thirds" threshold, in key-source "Production of F-gases" (2.E) emissions estimation with most detailed tier methods is not required for the two minor of the overall four sub sources (not specified here for confidentiality reasons). As all data are reported jointly and voluntarily, the exclusion of these two sub sources from data collection would not lower the specific expenditure of time and labour at the Federal Environmental Agency.

3. Key-source 2.F (Consumption of F-gases), however, offers considerable potential to save own resources in data collection. When ranking the eight sub sources by their percentage contributions to total key-source emissions, the by far weightiest sector is "1. Refrigeration and Air Conditioning" (53.9%), followed by "8. Other SF_6-Applications" (17.8%), and "3. Rigid Foam" (13%). Strictly speaking the highest level of data precision is required only for the first two sub sources as they alone make up more than two thirds of key-source emissions. Since emissions from "Other SF_6-Applications" are expected to decrease in the future, while "Rigid Foam" is expected to increase, we suggest applying the same high data precision to all three sub sources, which jointly accounted for 84.7% of total key-source emissions in 2003.

Less rigorous data collection requirements are necessary for 3. Fire Extinguishers, 4. Aerosols, 5. Solvents, 6.Semiconductor Manufacture, and 7. Electrical Equipment, altogether amounting to a bit more than 15% of total emissions of key-source 2.F.

4. Requirements at the level of single sources

The interpretation of the Federal Environmental Agency regarding the two-thirds emission threshold applies to "each hierarchy level". This means that within the three largest 2.F sub sources again only two thirds need to be estimated with more detailed tier methods. Applying this threshold criterion, in the fourth column of Table 2 those lower-ranking sources - or simply "sources" – can be read off, which contribute cumulative two thirds to the emissions of their respective sub sources (of 1st order).

When added up, in "Refrigeration and Air-Conditioning" the two largest of its six individual sources exceed the "two thirds" threshold by far: Commercial Refrigeration with 40.6% and Mobile Air-Conditioning of Passenger Cars with 35.7%. In "Other SF_6-Applications", likewise two sources are large enough to contribute jointly more than two thirds to sub source emissions: Soundproof Glazing (59.6%) plus Car Tires

(7.4%)[2]. Finally, in "Rigid Foam" the sources XPS-foam (48.4%) and OCF (40.7) alone represent together far more than the two thirds for which high data accuracy is required. (The percentages relate to the totals of the respective sub source emissions as per column 4 in Table 2.)

Conclusion: Within the key-source 2.F, only six individual CRF emission sources are left for more detailed tier approaches, if we strictly follow the above quoted UBA interpretation of the cumulative emission threshold "at each hierarchy level". The six identified single sources jointly count 65% of total 2.F key-source emissions.

5. Higher survey efficiency through source-specific precision demands

Generally, the two-thirds threshold should be applied in a flexible way. Wherever emission data can be obtained at higher precision level than required with acceptable expenditure, or where emission data deserve particular attention for political or other reasons, existing high data accuracy levels should be maintained.

The weight of the aforementioned six sources, jointly accounting for 65% of 2.F key-source emissions, is deemed too little, the more so as their proportion in key-source emissions is highly variable and might decrease over the next years. Therefore, we recommend additional sources to subject to more detailed methods of data collection.

Data accuracy in sub sources "6.Semiconductor Manufacture" and "7.Electrical Equipment", together accounting for 9% of 2.F emissions should not be dropped below the proven standard of the past years. Additional expenditure for the Federal Environmental Agency is insignificant. Emission relevant data are reported anyway in the frame of voluntary commitments. Furthermore, within the sub source "1.Refrigeration and Air-Conditioning", apart from - mobile - Air-Conditioning of Passenger Cars and –stationary - Commercial Refrigeration, the three sources Industrial Refrigeration, Transport Refrigeration (Vehicles), and Centralised Air-Conditioning Systems should be subject to detailed data collection, too, because of the strong connection of all these sources with each other. Pursuant to this proposal, in key-source 2.F for eleven individual sources (instead of just six) highest possible data precision is deemed required. Their joint share in total key-source emissions does not amount to just 65% but to even 84% in 2003, as per Table 2, col. 3.

Consequently, lower data precision requirements apply to the remaining 22 of the overall 33 individual sub sources, of which the key-source 2.F consists. These are the following:

1. Domestic Refrigeration, Refrigerated Containers, Room Air Conditioners, Heat pumps;
2. Mobile Air-Conditioning of Trucks, Buses, Agricultural Machines, Ships, and Railcars;
3. Integral PU Skin, Other PU Rigid Foam;

[2] The quantitatively larger source "Military Radar + Shoe Soles" is a collective sector, consisting of two individual sources, which are jointly reported for confidentiality. Thus, this "source" is not suited for more detailed higher tier methods.

4. Fire Extinguishers, Metered Dose Inhalers (MDI), Technical Aerosols, Novelties, Solvents;
5. Military Radar, Optical Glass Fibres, Particle Accelerators, Capacitors, Shoe Soles, Tracer gas.

The precision focus on the eleven largest sources does not at all imply that in the remaining 22 sources data shall be collected arbitrarily. The following second chapter that describes the future monitoring approach for each individual source in detail shows that the intended changes are not only designed to save resources at the Federal Environmental Agency but also to keep the data quality high enough. This is because the idea of sector-specific differentiated requirements allows for tailored approaches in smaller sources.

- In 11 of the 22 smaller sources, the main change is to carry out detailed data surveys or expert interviews no longer every year, but in larger time intervals. For the interim years, trend-based extrapolations are expected to deliver almost equal data quality. This approach is planned for all minor sources in "Refrigeration and Air Conditioning" named sub 1 and 2 in the compilation afore as well as for Particle Accelerators (under 5. above).

- In six other sources, namely Integral Skin, Other PU Rigid Foam (sub 3.), Fire Extinguishers (under 4.), Military Radar, Glass Fibres, Capacitors (under 5.) the effort for the Federal Environmental Agency is reduced, but data quality is not. This will be achieved by collecting the data with new instruments, mainly through the adjusted Environmental Statistics Law (UStatG).

- In four of the remaining six sectors, the existing approach should be kept up. This is because so far, in General Aerosols, Novelties (under 4.), Shoe Soles, and Tracer gas (under 5.) data have already been based on comparably rough expert estimations and trend extrapolations, in compliance with the IPCC GL.

- We suggest for only two sources that the present detailed data surveys of all domestic suppliers are discontinued and replaced by expert estimations. This applies to MDIs and Solvents (under 4.)

Experience tells us that the expenditure upon data collection in a particular emission source depends not so much on the absolute level of its emissions, but much more on the inner complexity of this source. The concept of differentiated precision requirement (two-thirds threshold) therefore facilitates a reduction in expenditure on data collection for the important key-source 2.F, which significantly exceeds the emission contribution of the respective 22 individual sources, which totals only 16% (100% minus 84%) of the key-source emissions.

II. Institutionalisation of established reporting channels

Collection of domestic sector-specific emission data is frequently based on data on the domestic market, i.e. on particular amounts of F-gases sold in final products to domestic customers. Activity data like "number of units sold to the domestic market" are often the indispensable starting point in estimation of domestic emissions, which then have to be entered into ZSE.

Sector associations or individual companies with leading market position know about such market data or can make it quickly available, but do not publish it for reasons of competition.

For reporting in the frame of voluntary commitments, data provided by single companies are mostly aggregated at the level of sector associations, and then made anonymous and submitted to the Federal Environmental Agency. In sectors without voluntary commitments, Öko-Recherche uses its contacts to experts from leading companies or from sector associations to obtain the necessary data. Only in one case such data collection is based on a written agreement with the informant.

A stipulation on periodical data reporting between companies or sector association on the one hand and the Federal Environmental Agency on the other hand is possible, even if a comprehensive voluntary commitment does not exist, nor is intended. Conceivable are written agreements on annual direct reporting of requested data to the Federal Environmental Agency.

Within this project, six companies with good knowledge about the market and six sector associations were addressed regarding their willingness to enter into written agreements with the Federal Environmental Agency on such direct data reporting. This was generally well taken, except for one company and one sector association. Thus not yet written agreements themselves but ten declarations of intent are currently available. The concerned sectors are the following:

- Room Air Conditioners
- OCF
- XPS Insulating Foam
- Fire Extinguishers
- Technical aerosols
- Novelties
- Solvents
- Cover gas in magnesium foundries (HFC-134a)
- By-product Emissions HFC-23
- Fugitive emissions from HFC and SF_6 production

This institutionalisation approach ensures the availability of data on the long-term, extending it beyond the duration of personal contacts. (Every change in personal data sources of data bears the risk of inconsistencies in the time series.) Furthermore, the data reporting is rendered more binding, and by that, time-consuming periodic inquiries of companies and associations about the data may become dispensable.

III. Enhanced data quality through new data collection instruments

1. The Environmental Statistics Law

So far the Environmental Statistics Law (UStatG) has hardly been used for the national emission inventory of fluorinated greenhouse gases, although data on use of HFCs and PFCs have been collected under this law since 1997. As the UStatG (dated 21.September 1994) was being amended during the running time of this project, the authors of this study were supporting both the Federal Environmental Agency and the Federal Statistical Office in exploring what the future part of UStatG in national F-gas emissions reporting could be.

1.1 Limited aptitude due to surveying of "Consumption for production"

In § 11 "Survey of substances contributing to ozone-depletion and climate change", paragraph 2 specifically states "fluoro derivatives of aliphatic hydrocarbons" to subject to the survey of substances with climate impact – thus HFCs and PFCs. The wording is as follows (see box).

Law on Environmental Statistics (UStatG 1994)
§ 11 Survey of certain substances contributing to ozone-depletion and climate change

(2) The survey annually collects from companies that use fluoro derivatives of aliphatic hydrocarbons with up to seven carbon atoms in amounts of more than 50 kg per substance and year for manufacture, maintenance, or cleaning of products, starting in 1997, for the respective previous year, data on type and quantity of these substances as such or in preparations.

The original objective of the survey was to document statistically not only the CFC phase-out but also the complementary phase-in of their substitutes. Annual data surveys for both substance groups addressed those companies who use HFCs and PFCs in excess of 50 kg per year for domestic manufacture and maintenance of products. (As to ozone-depleting substances, abbreviated "ODS", additionally data on domestic production as well as on import and export were asked for.)

The practical implementation is a total survey carried out by the Statistical Offices of the Federal States. Questionnaires are sent to more than 8,000 companies in overall fifty industrial sectors ("Wirtschaftszweige"), which in a preceding total survey had indicated annual use of more than 50 kg. (Addresses are continuously updated.) The questionnaire includes questions about ODS as well as on the use of HFCs and PFCs, which serve (1) as refrigerants (for first fill or maintenance/retrofitting), (2) as propellants for aerosol filling, (3) as blowing agents for the production of plastics and foams and (4) as other agents. A list of fluids, which contains, apart from ODS, all the relevant HFCs and PFCs as pure substances or as mixtures, is attached to each application the questionnaire inquires for.

In addition to the general questionnaire No. 11 (the numbering refers to the § 11 in the UStatG) two target group specific questionnaires are sent out: 11-45 and 11-50. The digits after 11 correspond to the industrial sectors 45 and 50 according to the classification of the Federal Statistical Office. Industrial sector 45 covers specialised workshops for refrigeration and air-conditioning; industrial sector 50 refers to sales and repair of passenger cars. These questionnaires are fairly short on purpose. They only inquire for refrigerant use, in order to reduce effort of surveyed companies.

The survey explicitly aims at the use of substances, more precisely at the quantity used for domestic manufacture of products. (In refrigerants also use for maintenance is inquired). The companies are not asked how much of this quantity is placed on the domestic market, thus causing domestic emissions. In case of e.g. aerosols, the amount of domestically filled propellants is inquired but not the amount sold to the domestic market, where the propellant emits through spraying. Likewise, stocks in closed systems are not surveyed nor amounts for disposal. The UStatG does not cover such activity data that are essential for the national emission inventory, which on its part follows CRF classification. Thus, UStatG is only of limited use for comprehensive emission inventories.

1.2. Benefit of UStatG in aerosol and foam sectors

At the same time the term "use for domestic production" (UStatG) is equivalent to the term "amount of fluid filled in new manufactured products". In CRF the latter is the first activity data (of three activity data categories) from which "manufacturing emissions" are calculated. The remaining activity data address fluids "in operating systems" and "in products at decommissioning". Consequently, in order to assess the first activity data, one can make use of the UStatG.

This suggests itself when determining the amounts of fluids used to fill aerosols or used for foam blowing. The sector-specific emission rates for filling/manufacturing vary, but they are known. They range from 1-2% on filling of MDIs, technical aerosols, and OCF, to 25% on manufacturing XPS foam (134a), and up to 100% on manufacture of PU integral skin and XPS foam (152a). Calculation of manufacturing (filling) emissions only requires that UStatG provides the amounts of fluids used for production within individual applications.

The present version of questionnaire 11 is not detailed enough to meet this requirement. It provides for only two different applications (aerosols and foams) the fluids can be assigned to. This causes uncertainties in OCF, which exhibits properties of both aerosol and foam. Furthermore, the surveyed data do not allow concluding on the specific foam applications, which have different emission rates on their own. Thus, the UStatG data can only be used for crosschecking of data obtained by other means, what may be useful, but is not satisfying.

The discussion between Federal Statistical Office, Federal Environmental Agency and the authors of this study has lead to the suggestion that the categories of aerosols and foams should be disaggregated further. The wording proposed for Part C of a new questionnaire 11 (now 10)[3] is as follows:

[3] The number of the questionnaire corresponds to the number of the paragraph in UStatG. In the amended law, the old §10 *Air Pollution* has been deleted so that the previous §11 is now §10; Thus, questionnaires addressing "certain substances with climate impact" are numbered 10 instead of 11.

Proposal for revised questionnaire 10 (previously 11)

Proposal Questionnaire 10 (former 11)

C Use as Propellant, Blowing Agent, Solvent, etc

Fluids	Used Fluids									
	as Propellant in Manufacturing of **Aerosols**			as Blowing Agent in Manufacture of **PU and XPS Foam**					as **Other Agent**	
	total	Thereof Medical Aerosols	Thereof Other Aerosols	total	Thereof One-Component Foam	Thereof PU Integral Skin	Thereof Other PU Rigid Foam	Thereof Extruded Polystyrene (XPS)	total	Thereof Solvent
	1	2	3	4	5	6	7	8	9	10
134a										
152a										
227ea										
236fa										
245fa										
365mfc										
43-10mee										
Other										

1.3. Low compatibility of UStatG with CRF in refrigeration and A/C

In refrigerants the situation is more complex. Subtraction of the amounts used for maintenance/retrofitting, which are indicated separately, gives the amounts of HFC and PFC refrigerants used in each industrial sector for production of equipment as pure substances (e.g. HFC-134a) or in blends (e.g. R-404A). When proceeding further, intrinsic limits of the UStatG become apparent. In refrigerants, the classification by industry sectors is for the most part incompatible with the CRF classification prescribed for the monitoring in the frame of emissions reporting to UNFCCC secretariat.

In CRF, the 2.F sub source "Refrigeration and Air-Conditioning" is disaggregated into individual sources according to the specific application-area of the equipment: refrigeration systems in household, trade (commercial refrigeration), industry, transport; air-conditioning systems in vehicles and in buildings. Only two of these six sources coincide with UStatG industry sectors. Household refrigeration matches UStatG sector 2971 "Manufacture of electrical household appliances". Of higher quantitative relevance is CRF source "Mobile Air-Conditioning" which corresponds to industrial sector 3410 "Production of motor vehicles". Here, UStatG surveys the annual amount of refrigerant (only HFC-134a comes into question) that is filled in new air-conditioning systems of passenger cars, trucks, buses, and tractors.

The UStatG, however, cannot provide specific information on refrigerant use in the four remaining CRF sources of commercial, industrial, transport refrigeration, and stationary air-conditioning, which have a very large share in total emissions of sub source "Refrigeration and Air-Conditioning". UStatG assigns two thirds of the refrigerants that are surveyed with questionnaires 11, 11-45 and 11-50 outside of the sector "Production of motor vehicles", to the industry sector 2923 "Manufacture of refrigeration and ventilation equipment, not for households", which is a business line of engine building industry. Another quarter is assigned to industry sector 4533, to which specialised refrigeration and air-conditioning workshops belong. In other words, the UStatG surveys the use of refrigerants for refrigeration and air conditioning equipment according to those industrial sectors in which the equipment is initially filled and subsequently maintained. No reference can be made to the application fields of this equipment as required by CRF.

1.4. Comparison of refrigerant data

In refrigerants the benefit of UStatG for F-gas emission inventory is smaller than in propellants and blowing agents. Nevertheless, some refrigerant data from UStatG surveys can be used to check data on domestic consumption for production (first fill) of refrigeration and air-conditioning equipment obtained elsewhere. Strictly speaking, total new refrigerant consumption as per CRF (because of adding up the consumption figures of each single CRF source) must be equal to the total refrigerant quantity used for production in all industrial sectors as per UStatG. In mobile air-conditioning, such a data check can be carried out even at the level of an individual sector; but this is the only one. As UStatG and CRF data always coincide for the aggregated amounts of individual refrigerant types, there may be a considerable benefit for the comparison with other data sources. This especially applies to refrigerants like HFC-23, PFC-116, PFC-218, HFC-227ea, R-410A, and R-508B, which are used in small amounts. This is joined by the fact that some of them are used in only one or two sources.

The UStatG is, however, more than a tool to check-up and improve other refrigerant data sources concerning the use for production. It can also be applied to emissions from banks. All questionnaires include inquiries about refrigerant use for maintenance (= topping up existing equipment). As it is common international standard to consider refilled quantities, which compensate for emissions, equal to emissions themselves, at least in the medium-term, the UStatG in principle allows a comparison of aggregated emissions for individual refrigerants. In case of mobile air-conditioning this can even be done at the level of a whole sector. Questionnaire 11(10)-50 has been specifically designed for this purpose.

1.5. Opportunities by new questionnaires and amended UStatG 2005

The discussion between Federal Statistical Office, Federal Environmental Office and the authors of this study revealed two obstacles for this kind of indirect and summary emission survey. Firstly, refrigerant use for refilling in existing equipment and use for first filling into retrofitted equipment must no longer be addressed as the same activity in questionnaires. Initial filling of retrofitted old equipment with HFCs instead of ODS is inherently a first fill and thus production, no maintenance. Secondly and of much greater importance, the valid legal threshold value of 50 kg annual use per refrigerant is too high to cover the top-up activities of the numerous small service companies.

The new 2005 questionnaires for the 2004 survey follow the suggestion that three instead two answers to the question about refrigerant use should be possible: (1) Initial fill of new equipment, (2) First fill of retrofitted old equipment, (3) Maintenance of existing equipment.

The recommendation to lower the threshold quantity, aiming at the UStatG itself, not its implementation, has also been followed for the most part. Paragraph 1 of § 10 of the new "Law on increased efficiency of environmental statistics", which replaced the existing UStatG in July 2005, does not only additionally provide for data surveys of production, import and export of HFCs and PFCs, but contains also a new minimum threshold per substance and year of 20 kg.

The wording of the new §10 is shown below. The change in numbering is a result of the fact that the former §10 "Air Pollution" has been deleted. It should be noted that data surveys of ODS are no longer possible. At the same time the first-time inclusion of sulphur hexafluoride represents a clear improvement compared to the old UStatG.

Law on increased efficiency of environmental statistics
§ 10 Survey of certain substances with climate impact

(1) The survey collects data on fluoro derivatives of aliphatic or cyclic hydrocarbons with up to six carbon atoms from companies who

1. produce, import or export such substances, or
2. use more than 20 kg per substance and year for production, service, maintenance or cleaning of products.

Starting with reporting year 2006, the survey inquires the parameters of type and quantity of the pure substances or the substances in preparations.

(2) The survey collects data on sulphur hexafluoride from companies who

1. produce, import or export or
2. place more than 200 kg annually on the domestic market.

Starting with reporting year 2006, the survey inquires the parameter quantity of the substance and in case of number 2 additionally the intended use. The survey does not apply to companies manufacturing products and equipment that require SF_6 in order to be functional.

1.6. The survey of sulphur hexafluoride

Sulphur hexafluoride (SF_6) is no CFC substitute and was therefore not surveyed pursuant to the previous UStatG. The substance with extremely high global warming potential (GWP 23,900) has been covered by the Kyoto Protocol since 1997. SF_6 consumption and emissions are reported annually according to CRF. In connection with the revision of the UStatG it was discussed if SF_6 could be included in the F-gas survey - at acceptable additional administrative effort.

SF_6 contributes 76% to the emissions of key-source 2.C. "Metal Production" (only F-gases) through its use in magnesium and aluminium foundries. Emissions of key-source 2.F "Consumption of F-gases” are 24% SF_6 emissions from applications like soundproof glazing, electrical equipment, car tires, military radar, tracer gas, etc.

In case of SF_6, the design of the UStatG, the exclusive surveying of the domestically used amounts of a substance, does not restrict its emission inventory benefit to such an extent as in HFC refrigerants. Five of the ten SF_6 uses ("intended uses" according to new UStatG) are open applications. Here, domestic consumption is equal to domestic emissions - either directly or with some timely delay, so that no further data sources apart from UStatG is necessary. In the remaining applications, the UStatG can provide useful information to crosscheck data obtained elsewhere.

In Germany, all SF_6 is supplied to domestic users either directly by the producer or indirectly by one of the about ten specialised gas-dealers. Regarding SF_6, since many years the national F-gas inventory relies on gas dealers' documentation and estimation of SF_6 distribution channels. Thus, Federal Statistical Office, Federal Environmental Agency, the authors of this study, and representatives of gas-dealers discussed about legal establishment of this proven method of data collection. The approach should allow avoiding time-consuming inquiry of the numerous single users, and achieve the same result by asking the small number of gas-traders.

All parties agreed that in case of SF_6 only those companies should be addressed, who annually "place" a minimum amount of SF_6 on the market, i.e. sell it. These companies are asked to list anonymously their sales by ten applications (industrial sectors). For this purpose a specific questionnaire (10-51) is to be designed, a draft already exists. The questionnaire can be used once the new UStatG provides for surveying SF_6. This is the case now. In its essence, the questionnaire consists of the attribution of the SF_6 sales (kg) to different applications – as shown below.

Proposed Questionnaire 10-51
B Placing/Sales of Sulphur Hexafluoride

Did you sell/place sulphur hexafluoride in excess of **200 kg per substance** in the year 200X? *Please tick.*	
If yes, please enter the total amounts of sulphur hexafluoride in the following table, the inquiry of your company is then finished.	
Industrial Sector	- kg in the year 200X -
Magnesium foundries (Cover gas)	
Aluminium foundries (Cleaning gas)	
Producers of windowpanes and windows (Insulating gas)	
Electric Utilities (Insulating gas)	
Electrical Industry (Insulating gas)	
Repair shops, Tire traders	
Military, Armed forces (Military purposes)	
Semiconductor industry (Etching gas)	
Chemicals suppliers	
Miscellaneous	
Total	

1.7. Conclusion

Owing to (a) the new questionnaire (10-51) for SF_6, (b) the revised part about propellants/blowing agents in questionnaire 10, (c) the adjusted structure for entering refrigerant use in the three existing questionnaires (10, 10-45, 10-50), (d) the updated list of used pure and blended HFCs and PFCs, and (e) the reduction of the threshold quantity from 50 to 20 kg (HFC, PFC), the revised UStatG can make a considerable contribution to the annual emission inventory according to CRF. This mainly applies to the domestically used amounts for manufacturing of new products. In some cases emissions can be covered directly or through intermediate steps programmed in the ZSE database (Centralised System Emissions) at UBA.

2. New database-systems for refrigerant management

During the recent years two databank-based systems for the management of refrigeration and air-conditioning equipment have been developed, which have not been used for data collection so far: EcoKlima and VDKF-LEC. In Germany, data from these two projects are potentially available for the national F-gas emission inventory. In the following, the systems are presented briefly, and their suitability for future determination of emissions in refrigeration and air-conditioning is discussed.

2.1. EcoKlima

The following information mainly comes from Mr Günter Lanz from the Hesse Ministry for Environment, Rural Areas and Consumer Protection (Conversation held on 19.07.2005) and from www.ecoklima.de.

The tool has been developed by the Federal Technical School for Refrigeration and Air-Conditioning in Maintal as part of the "Environmental Alliance of Hesse". The Federal Technical School is now and in future in charge of maintaining the software (e.g. regarding new legal and technical developments) and the data evaluation. EcoKlima is an internet-based application for management, documentation and maintenance of stationary refrigeration and air-conditioning equipment. The application is dedicated to specialised enterprises for refrigeration and air-conditioning as well as to companies who carry out maintenance themselves. It contains a database with all technical and environmentally relevant information regarding the available refrigerants, especially data regarding ozone-depleting potential and global warming potential in case of emissions as well as further supportive means including data sheets, draft contracts, standard maintenance schedules, etc. Companies can use the application at an annual fee of about €100.

The objective of EcoKlima is to enable owners of refrigeration and air-conditioning equipment as well as service enterprises to collect, manage and online report audit proof equipment data, refrigerants used and repairs made to the competent authority.

EcoKlima has the following functions relevant for national emissions inventory:

- Management of data on refrigeration and air-conditioning equipment,
- Management of data on maintenance and repairs as well as on disposal and topping-up of refrigerants,
- Information on refrigerants, regulations and provisions regarding their use as well as for leakage tests,
- Evaluation of mass balances (including disposed, used, substituted, and emitted refrigerant amounts).

As data on filling, topping-up and disposal of refrigerants are collected, EcoKlima contains the emission relevant data of the equipment managed by this database system. The Federal Technical School for Refrigeration and Air-conditioning intends to carry out periodic evaluation of the system data. Evaluation relevant for national reporting, i.e. annual emissions differentiated by types of equipment and refrigerant, can be arranged with the Federal Technical School in advance. Optionally, evaluation can also be carried out directly by the Federal Environmental Agency.

2.2. VDKF-LEC

The following information comes mainly from Mr Yorick Lowin, who is in charge of the system at VDKF (conversation held on 26.07.2005) as well as from www.vdkf-lec.de.

The system for leakage and energy-control (LEC) developed by the Association of German Refrigeration and Air-Conditioning Contractors (VDKF) will be mandatory for all members of the association – at present around 1,000 companies, i.e. about 50% of the existing independent service enterprises for refrigeration and air-conditioning in Germany – starting on 01.01.2006. In contrast to EcoKlima, the target group of the system generally consists of contractors for refrigeration and air-conditioning, who service numerous stationary refrigeration and air-conditioning plants (potentially mobile transport refrigeration systems) in various fields of application.

The application has been jointly developed by VDKF and the Kassel-based Centre for Integrated Environmental Protection (ZiU). It claims to offer an overall solution for the legal documentation and reporting requirements for all kinds of refrigeration and air-conditioning equipment. Similar to EcoKlima an annual fee of €120 has to be paid.

VDKF-LEC has the following functions relevant for national emission inventory:

- Management of equipment data (inclusive of keeping a log-book),
- Recognition and avoidance of contraventions of applicable legislative standards (leakage controls, recording obligations),
- Evaluation of mass balances and calculation of environmental effects (ODP, GWP, CO_2)
- Support for planning of service and maintenance
- Documentation of refrigerant use: first filling, topping-up, disposal of the respective refrigerants by types and amounts.

In contrast to EcoKlima, VDKF-LEC is not an internet-based application, but is installed directly at the refrigeration and air-conditioning contractor. Monitoring of all emission relevant data is possible at the plants being serviced by the contractors. An export function allows for submission of anonymous data to the VDKF, so that this data can then be evaluated statistically for the whole sector.

Like EcoKlima, VDKF-LEC is to contain data on the operating emissions from each system by means of recorded topping-up amounts. Evaluation aiming at the collection of emission data for national reporting was provided for when the databank was developed.

VDKF is willing to submit respective data to the Federal Environmental Agency and to run specific evaluation on request (e.g. annual emissions differentiated by equipment and refrigerant type). The first general test-evaluation is going to be carried out in 2005; afterwards evaluation is to take place annually.

2.3. Usability of the refrigerant databases for national reporting

Data collected and evaluated through EcoKlima or VDKF-LEC can only be used for estimations of typical emissions from entire or at least partial application sectors – mainly in commercial, industrial, transport refrigeration and stationary air-conditioning – provided that a sufficiently high number of plants is covered by or entered into the databases – be it the one or the other. For this, information on the representativeness of the various types of equipment already available in the databank systems is indispensable.

Both databank-based systems are supposed to be able to provide useful data for national emissions reporting as a start only from partial sectors in commercial and industrial refrigeration, in case of VDKF-LEC possibly also in transport refrigeration and heat pumps. Equipment in the latter applications is also being serviced by independent contractors using VDKF-LEC, while operators of such systems can use EcoKlima. However, for these two heterogeneous sectors complete coverage of existing equipment in the short-term is even less likely than in commercial and industrial refrigeration and in stationary air-conditioning.

For collection of activity data as well as for extrapolations in each sector, the question is of decisive importance, what the actual share of database-covered equipment in the total stock of operating equipment at the national level is. This question deserves special attention also facing the fact that refrigeration and air-conditioning contractors are not the only players in equipment service and maintenance, in some applications not even the most important ones compared to in-house staff or to customer service of industrial refrigeration and air-conditioning companies.

At present both systems have still a limited number of participants. Furthermore, in both systems must be clarified how to conduct extrapolations from limited equipment numbers over the short and medium term. At the same time, calculation of emission factors for various types of equipment is possible even prior to full coverage of existing equipment.

This may be a very important contribution to revision and further development of the emission factors, which are currently used in national F-gas emission inventory.

Second Chapter.
Existing and Revised Monitoring for all F-Gas Sources

In the following the present monitoring approach for each individual source within the key-sources 2.C Metal Production, 2.E Production of Halocarbons and 2.F Consumption of F-gases is described briefly, and a future approach is proposed. Firstly, the differentiated data precision requirements on individual sources are taken into account. Secondly, the use of new means of data collection is considered: (1) voluntary agreements on direct reporting to the Federal Environmental Agency, (2) amended Environmental Statistics Law (UStatG) and (3) database systems for refrigerant management.

I. PFCs and SF6 in Metal Production (2.C)

1. SF_6 in Magnesium Foundries

Application: SF_6 serves as protective cover gas to prevent oxidation and burning over the molten metal. Yet consumption is equated with emissions. Currently, about 15 foundries use SF_6 in amounts of 40 to 10,000 kg/y. Pursuant to the forthcoming EC-Regulation use of this gas in excess of 850 kg/y is forbidden from 2008 onwards. Currently, at the majority of the concerned die casting foundries conversion is being tackled, in most cases HFC-134a is used as substitute.

Present monitoring approach: Öko-Recherche asks for annually purchased amounts of SF_6 – since 2002 also HFC-134a - at each single foundry. Crosschecking had raised doubts about the data on SF_6 supply to the application "Foundries" obtained by gas dealers, which could be resolved only at user level. For example, triplication of supply to a large foundry resulted from the fact that the additional quantity was exported. Furthermore, it became apparent that several foundries had been supplied by smaller gas-suppliers, which had not been addressed before.

Future monitoring approach: Consumption data is collected with the help of the amended UStatG (proposed questionnaire 10-51, industrial sector: "magnesium foundries – cover gas"). Questionnaires are sent to gas suppliers. In contrast to the previous procedure all existing gas-dealers (about ten) are addressed, hence coverage of the complete amount of gas is to be expected.

2. HFC-134a in Magnesium Foundries

Application and present monitoring approach: HFC-134a has been tested as substitute for SF_6 since 2002 and is used as cover gas in individual cases. So far, consumption data has been obtained as part of the data collection for SF_6 by addressing all foundries directly.

Future monitoring approach: Time-consuming direct inquiries can be avoided also in case of HFC-134a, although gas-suppliers cannot be addressed here, because trade in HFC-134a (being a refrigerant!) is too fragmented. However, use of HFC-134a as a cover gas for magnesium die-casting has been patented so that (according to applicable law) buyers have to pay quantity-dependent fees to the patentee, AMT – Advanced Magnesium Technologies. The German representative of AMT is willing to sign a written agreement with the Federal Environmental Agency on annual reporting of the aggregated HFC-134a sales that he can derive from the cashed fees. This procedure is considered sufficiently accurate.

Note to emission factor: As in case of SF_6, decomposition of the gas upon use is being discussed. Yet, emissions are equated with consumption. As soon as IPCC proposes emission factor other than 100%, emissions estimation will make use of it.

3. SF_6 in Aluminium Foundries

Application: SF_6 has not been used as an additive to inert gases (nitrogen and/or argon) for melt cleaning for several years. In the late nineties, however, application of pure SF_6 started in a few foundries that manufacture specialized allows. Meantime, considerable amounts are used and account for more than half the F-gas emissions from the whole key-source 2.C (2003). As long as no consolidated findings on the degree of SF_6 decomposition in the hot melt exist, consumption is equated with emissions.

Present monitoring approach: Although only few users exist, SF_6 consumption figures are surveyed among the gas-suppliers.

Future monitoring approach: The currently established approach (data collection from gas dealers) facilitates the inquiry through the amended UStatG. The proposed questionnaire 10-51 addresses all suppliers of industrial gases, and asks specifically for the aggregated sales to aluminium foundries (cleaning gas).

4. PFCs from Aluminium Production

Generation: Emissions of the PFCs CF_4 and C_2F_6 do not result from specific use of the gases, but arise as by-product of electrolytic reduction of aluminium oxide to aluminium. New smelters in connection with computer-based feeding technologies have helped reduce emissions significantly.

Present monitoring approach: Based on a voluntary commitment (June 1997), the Primary Aluminium Chapter in the Federation of German Aluminium Industries (GDA) annually reports emissions from the five German smelters. Data stem from two measurement-based surveys carried out in 1996 and 2001 (following tier 3b, IPCC GL 2000). The monitoring report with detailed information on the single smelters is not open to the public, but is submitted to the Ministry of Environment.

Future monitoring approach: The voluntary commitment ends in 2005. Due to the positive experiences with the present monitoring system, the authors of this study suggest prolongation of the current approach.

II. Production of Halocarbons and SF_6 (2.E)

1. HFC-23 By-product Emissions from HCFC-22 Production (2.E.1)

Generation: In the synthesis of HCFC-22, HFC-23 inevitably arises as a by-product up to a level of 3%. HCFC-22 itself serves either as refrigerant (regressing) or as feedstock for the plastic PTFE (stable demand). In the two German plants (Frankfurt and Bad Wimpfen) HFC-23 is separated, captured and decomposed or – to a certain extent – marketed as final product. A certain amount of gas is emitted to the atmosphere unintentionally. The Frankfurt plant is directly connected to the adjacent thermal cracking plant so that emissions of HFC-23 worth mentioning do not occur. In Bad Wimpfen some emissions still occur – at a considerably lower level than in the past - although HFC-23 is captured, filled in special pressure-resistant containers, and transported by trucks to the thermal decomposition plant in Frankfurt.

Present monitoring approach: The operator of the plant, Solvay Fluor und Derivate GmbH, measures the emissions and reports the data once a year to Öko-Recherche. The latter had entered into a commitment "to handle them with utmost discretion and to pass them only to directly involved staff members of the German Umweltbundesamt in the framework of coordination and for data aggregation purposes".

Future monitoring approach: The amended UStatG cannot be used for surveying plant emissions. For the near future, we suggest that the bilateral agreement between Öko-Recherche and Solvay Fluor is turned into a bilateral agreement between the Federal Environmental Agency and the Solvay Fluor und Derivate GmbH. Solvay is willing to do so.

2. Fugitive Emissions (2.E.2)

2.1 HFC-134a
2.2 HFC-227ea
2.3 SF_6

Generation: Domestic production of the three F-gases is associated with some fugitive emissions. Plant operators establish the emitted amounts by means of mass balancing. The latter is considered the difference between the output of final product filled into tanks and weighed on the one hand, and the expected amount of final product based on the raw material input, on the other hand.

Present monitoring approach: The operator of the installations, again Solvay Fluor und Derivate GmbH, annually reports the figures to Öko-Recherche, based on the above named bilateral agreement.

Future monitoring approach: Again, an agreement on direct reporting between the plants operator and the Federal Environmental Agency is suggested. (Following the amended UStatG, Solvay has to report only manufactured amounts but not emissions, to the competent State Statistical Office).

III. Consumption of HFCs, PFCs and SF_6 (2.F)

1. Refrigeration and Air-Conditioning (2.F.1)

1.1. Domestic Refrigeration

Application: Household refrigerators/freezers just marginally (0.03%) contribute to emissions from the large 2.F sub source "Refrigeration and Air-Conditioning”. Only natural refrigerants are being filled in domestically manufactured equipment. Emissions of HFC-134a (EF = 0.3%) banked in refrigerators trace back to 1994, the only year the fluid was fully used. In addition to that, some HFC-emissions arise from equipment being imported, accounting for 1% of the annually sold refrigerators.

Present monitoring approach: The annual increase in bank amounting to 1% of equipment sold to the domestic market has been estimated by leading manufacturers. In ZSE, the HFC amount in annually sold equipment increases the cumulated HFC bank which is available as time series as of 1994. Using operating emission factor of 0.3%, the system calculates bank emissions automatically.

Future monitoring approach: Due to the tiny size of the source, high data precision is not required. The 1% share of new equipment filled with HFCs should be extrapolated for the time being and should be reviewed in intervals of three to five years. From 2009 onwards, the ZSE – which assumes equipment lifetime of 15 years – will show the HFC amounts entered 15 years before as amounts for disposal. A (country-specific) disposal emission rate of 30% will then be applied to them.

1.2. Commercial Refrigeration

Application: With 22% share in emissions of key-source 2.F and 41% of sub source "Refrigeration and Air-Conditioning”, this sector is the largest single HFC source and hence subject to a Tier-2 approach in data collection. This is no easy task as the sector is the most heterogeneous as to design, size, refrigerant type, and leak tightness of equipment; in addition to supermarkets, it also covers the wide area of refrigerating equipment in butcheries, gastronomy, agriculture, etc. In contrast to household refrigerators or passenger car air-conditioners, mass-produced uniform systems are not as frequent as custom-made, adjusted solutions. As the specialist companies supplying and servicing equipment are also very heterogeneous (including refrigeration craftsmen, industrial companies, and in-house staff) direct surveying of annual increase in refrigerant bank is not yet feasible. Today, largest input HFC is the blend R-404A, which has even become more important than HFC-134a. R-407C also plays an important role, and – at very low temperature – HFC-23 and PFC-116 are used. Currently large banks of HCFC-22 still exist.

Present monitoring approach: The specific approach used only for commercial and industrial refrigeration, does not consist of determining the national refrigerant banks based on the amounts contained in new equipment adding to domestic stock, but in doing the contrary. Based on in-depth empirical bottom-up expert estimations documented in UBA-report15/05, in 2002-2004 national refrigerant banks were estimated in detail for their final or full-size state, when all existing equipment does do no longer run with any chlorine-containing refrigerants. This modelled final bank is assumed stable over the medium-term. In contrast to sharply growing applications like stationary and mobile air-conditioning, stability of the bank seems to be realistic for stationary refrigeration. In final state, emissions can be calculated directly, because the inner structure of the bank has been modelled by equipment design, size, refrigerant composition, and specific emission rates.

Final state will be achieved gradually, unless measures ahead of time are required by law (as in case of CFC-12), through replacement of old equipment containing chlorinated refrigerants by new equipment with HFCs, on a year-by-year basis. Thus for each individual refrigerant annual input through newly added equipment to the existing refrigerant bank can be roughly determined. Annual (balanced) input is equal to full bank size divided by average equipment lifetime (10 years usually).

The year 1997 is viewed the first for HFCs to become common in all types of new equipment. In earlier years, new equipment often still contained HCFC refrigerants. Thus, the final state is not reached before 2007. Until then, annually disposed HFC amounts are lower than the HFC quantities in new equipment of the same year.

Future monitoring approach: Also in the future calculation of emissions will be based on the model of the bank entered into ZSE. Plans are to refine its components and render them more realistic gradually. This shall also be done with the help of the UStatG, but mainly with the help of the databank-based monitoring systems.

So far, the most important means to check the data generated by the model is the annual inquiry of the four producers Solvay, DuPont, Ineos, and Arkema (previously Atochem) about their aggregated amount of national refrigerant sales to all sectors of stationary refrigeration. Annual consumption for new installations and topping-up in commercial and industrial refrigeration calculated from the model can be compared with the data provided by the producers. UStatG can also be used for this purpose as it requires collection of overall refrigerant amounts used domestically, allowing for separation from consumption in mobile air-conditioning. However, this is not more than a plausibility check that might lead to corrections of the model. Producers and UStatG do not differentiate between commercial and industrial refrigeration. Producers do not distinguish between first fill and topping-up, let alone between equipment with low and high emission rates.

More detailed information about the structure of equipment in commercial refrigeration regarding emissions upon commissioning, operation and disposal as well as equipment type, lifetime and refrigerants used are expected to be provided by the currently developed databank-systems for refrigerant management. Following statements of their developers, data on individual refrigeration systems will be so detailed, that specific evaluation rounds delivering data suitable for national reporting will be possible (see section 1, III, 2).

In the medium-term, however, expert knowledge will still be necessary, also in order to check the suitability of the databank-based systems.

1.3. Transport Refrigeration

This single source has a low share of 3.5% in sub source emissions. About 75% of its emissions stem from refrigerated vehicles.

1.3.1. Refrigerated Vehicles

Application: Refrigeration units, which vary in dimensions and refrigerant charge depending on the cargo hold, are mounted to the roof or the front of insulated vehicles. Aside from refrigerants that are only temporarily used for service, three HFC-refrigerants are used: R-134a, R-404A, and R-410A.

Present monitoring approach: Entering of activity data into ZSE is carried out in two steps. The German Federal Office for Motor Vehicles (KBA) annually publishes new registrations of trucks and trailers for the previous year, split into 23 weight categories. First, these 23 categories are reduced to four main categories. Then a refrigerant model developed and last updated in 2004 with the help of sector experts is used. The model comprises average refrigerant charges in kg and the proportions of the individual HFCs in percent, for each of the four main weight classes. By combining the annual number of newly registered refrigerated vehicles and the refrigerant model, the annual HFC-input to the refrigerant banks – available as time series in ZSE - can be calculated. The ZSE emission factor of 15% automatically generates bank emissions for each refrigerant. (The same applies to emissions from domestic filling). Disposal emissions are calculated by multiplying first fill amounts dating 10 years lifetime back with the disposal emission factor (EF in ZSE = 30%).

Future monitoring approach: It seems wise to keep on using both the official data from KBA as well as a robust refrigerant model. The latter is the crucial point in determination of activity data. Refrigerant charges specific to weight categories as well as the refrigerant composition by types are subject to changes and therefore need periodical updating (in intervals of about three years) in order to limit data errors.

Systems for databank-based refrigerant management, currently being under way, may contribute to both updating the refrigerant model and checking emission factors (filling, bank, disposal), and thus increase data accuracy. Developers of the systems envisage random sampling of activity data and emissions even for transport refrigeration. A prerequisite for this is that a sufficiently high number of refrigerated vehicles have been included into the systems.

UStatG may be used for data checks with some reservations. Questionnaire 10-50 asks for refrigerants used for repair and maintenance of cars (WZ 5010, 5020) but does not differentiate between topping-up of refrigeration systems and air-conditioning systems. In both cases, HFC-134a is used as refrigerant. Only the refrigerants R-404A and R-410A, which are exclusively used in refrigerated vehicles within mobile systems, can be clearly attributed to transport refrigeration.

The support from sector experts remains necessary also in the future, even though the experts do not need to be interviewed every year.

1.3.2. Refrigerated Containers

Application: Refrigeration units with the refrigerants HFC-134a or R-404A are mounted to container boxes that are carried on ships. Different opinions exist to whom emissions from this source should be assigned. Losses of refrigerant predominantly occur in international waters, for which none of the national states is legally responsible. Corresponding to Germany's share of about 10% in world trade, 10% of emissions from the worldwide fleet of reefer containers are attributed to national emissions.

Present monitoring approach: The data on annual numbers of new reefer containers is collected by the World Container Census, and is published on the internet by the information service World Cargo News (www.worldcargonews.com). A refrigerant model in ZSE is used to calculate the HFC quantities annually filled in new refrigeration units, on global level. The model includes average refrigerant charge per container for HFC-134a and R-404A, respectively, as well as the shares of the refrigerants in percent. From the numbers of units and the refrigerant model the HFC amounts result, which then are divided by ten and entered into ZSE. As the ZSE contains the accumulated refrigerant bank as time series, emissions from banks and emissions from disposal at the end of the lifetime are calculated automatically.

Future monitoring approach: As long as emissions from refrigerated containers are broken down and assigned to national emissions, the existing approach seems to be the most appropriate. The refrigerant model varying as to refrigerant charges and types should be updated jointly with sector experts in intervals of 3 to 5 years.

1.4. Industrial Refrigeration

Application: With 6.5% of emissions of key-source 2.F and 12% of the sub source "Refrigeration and Air-Conditioning”, industrial refrigeration is one of the larger single sources. As in commercial refrigeration, numerous refrigerants are applied - with R-404A being the most important one, followed by HFC-134a. In industrial refrigeration, systems tend to be individual solutions even to a higher extent than in commercial refrigeration. Service is carried out by in-house staff, but also by external contractors and companies. As in commercial refrigeration, direct determination of annual input of new refrigerants is impossible due to sector heterogeneity.

Present monitoring approach: Based on empirical data, an in depth model for the HFC bank in its final state – analogous to the one in commercial refrigeration – has been developed (see UBA report 15/05). In the model, present refrigerating and freezing needs being satisfied by fluorinated refrigerants with and without chlorine are assumed stable in the medium-term. Based on this assumption, annual refrigerant consumption can be calculated by division of full bank by number of years of equipment lifetime. "Discounts” resulting from the use of HCFC-22 in new equipment until 1997 are considered. Amounts for disposal correspond to the refrigerant input dating back one full equipment lifetime. Emission factors are taken from expert estimations and are part of the ZSE like the refrigerant model itself.

Future monitoring approach: Further-on in the future, emissions determination should be based on the refrigerant model of the final bank. Plans are to systematically refine its components and render them more realistic. This should chiefly be done with the help of databank-based systems (e.g. EcoKlima, VDKF-LEC). As to UStatG, the same possibilities and restrictions have to be considered as in commercial refrigeration. Support of experts will be necessary in the future, too.

1.5. Stationary Air-Conditioning, Room Air-Conditioners, Heat Pumps

Stationary air-conditioning accounts for 3.7% emissions of the sub source "Refrigeration and Air-Conditioning", if room air-conditioners (0.5%) and heat pumps (0.1%) are included. Thus, less rigorous precision requirements need to be applied. Nevertheless, data collection following tier 2 approaches (bottom up) is suggested also for the future.

1.5.1. Centralized AC Systems

Application: Air-conditioning systems in the performance range above 20 kW refrigerating capacity are used to provide comfortable temperatures in whole buildings or large rooms. Mainly central systems with refrigerant in the primary and water in the secondary cycle (chillers) are used; in the lower performance range also directly evaporating systems are common. The HFC-refrigerants are R-407C and R-134a. Emissions occur during filling, from refrigerant banks and on disposal.

Present monitoring approach: Emissions calculation in ZSE is based on a refrigerant model (Status: Early 2003) which splits AC systems into three classes of performance. Each category is associated with a particular compressor type: Centrifugal compressor in the upper, screw compressor in the medium, and reciprocating or scroll compressor in the lower performance range. Typical refrigerants and average HFC charges are assigned to each of the three categories. The refrigerant model, which also contains equipment lifetimes, was jointly developed with sector experts. These experts annually estimate the number of newly installed equipment. After this number has been entered into ZSE where the refrigerant amounts are available as time series, emissions from filling, use, and disposal are calculated automatically, using the emission factors, likewise available in ZSE.

Future monitoring approach: Calculation of emissions should continue being based on expert estimations of the number of annually newly installed systems as well as on the ZSE refrigerant model, which needs to be updated by experts in the near future (2005/2006). In the medium term, the structure of the refrigerant bank can be refined with the help of databank-based systems. This applies also to the emission rates that are based on expert estimation up to now. UStatG is not qualified to provide specific data on emissions from air-conditioning systems.

1.5.2. Room Air-Conditioners

Application: Room air conditioners, which can be mobile, split, or multi-split devices, are used to produce comfortable temperatures inside individual living and working rooms or whole storeys. Equipment in the performance range below and slightly above 20 kW shows a strong increase in sales quantities. Equipment is not manufactured at national level but is completely imported. Since 1998, R-407C and increasingly R-410A have been used as refrigerants instead of HCFC-22.

Present monitoring approach: As in central air conditioning, emissions calculation is based on a refrigerant model in ZSE. It embodies the ratio between 407C and 410A, the average refrigerant charges as well as lifetimes and emission factors for the device categories "mobile", "split", and "multi-split". The number of newly sold systems by categories is estimated annually by experts on request and then entered into ZSE.

Future monitoring approach: In this area, databank systems can at most be used for (more or less complete) partial data collections even in the long-term, but the systems will never achieve full data coverage. Therefore, they are not considered superior to expert estimations of activity data. All importers of room air-conditioning systems (around 30) annually report their sales data to the trade magazine CCI.Print, which in turn informs the importers (only the importers!) about the overall sales figures. This is why the importers have exact knowledge about size and structure of the market. They should be asked for estimations also in the future. With their support, also the refrigerant model can be updated periodically.

1.5.3. Heat Pumps

Application: By means of an electrically driven refrigeration cycle heat pumps produce useful heat from ambient heat. The refrigerant absorbs ambient heat of low temperature and changes it to heat of higher temperature. In this report, heat pumps, having an extremely low share in total F-gas emissions, are categorized sub air-conditioning equipment, because both systems are used to control room temperature. (In principle, heat pumps can really be operated as air-conditioners).

Present monitoring approach: Emissions calculation is based on a refrigerant model developed with the help of sector experts. The model embodies for each of the four heat pump categories specific average refrigerant charges and the specific refrigerant type composition, in addition to equipment lifetimes and emission rates. The number of newly installed systems at national level is published annually by the Federal Association Heat Pumps (BWP), broken down into the four categories: air, water, ground, and hot water. After entering of the BWP data into ZSE emissions are calculated automatically.

Future monitoring approach: The existing system is much more detailed than necessary to meet the precision requirements of a very small emission source that contributes just 0.1% to sub source emissions. Nevertheless, we recommend adhering to the existing system because the number of annually installed systems differentiated by four categories are collected and published anyway. The refrigerant model should be updated every 3-5 years with the support of sector experts. It is not yet clear if databank-based systems will be able to contribute to this task.

1.6. Mobile Air-Conditioning

1.6.1. Mobile Air-Conditioning of Passenger Cars

Application: Air-conditioning systems in passenger cars account for more than 19% of emissions from key-source 2.F; thus being the second largest single source within this key-source. The existing monitoring approach complies with high data precision requirements. Due to the rapidly increasing share of new cars with air conditioning, saturation is foreseeable. Emissions occur on filling, operation, and disposal. According to the forthcoming EC-F-Gas-Directive, the refrigerant HFC-134a has to be phased-out between 2011 and 2017.

Present monitoring approach: Determination of the new refrigerant quantity adding to the existing bank, which is available as time series in ZSE, is carried out in three steps. In January, the previous-year number of newly registered passenger cars is available at the KBA at the national level differentiated by manufacturers and models. In addition, the number of newly manufactured cars is available at VDA, at the same time, again by manufacturers and models. Next step in monitoring is to survey the average AC penetration (AC ratio in %) and the average refrigerant charge for newly registered as well as for newly manufactured cars. After entering all these data into ZSE, emissions from filling, use, and disposal are calculated automatically because both average lifetime of passenger cars and emission rates are available in ZSE.

A characteristic of passenger car air-conditioning is the fact that AC ratios and refrigerant charges are not derived from a refrigerant model based on expert estimations. Since 1995, about 30 manufacturers of passenger cars have been inquired annually about AC ratios and system charges of the 5 to 15 car models they make. In so doing, 100% of the newly registered cars from domestic manufacturers and about 90-95% of newly registered cars from foreign manufacturers are surveyed completely. As also the use-phase emission rate (EF=10%) is based on recent empirical studies, data precision is above average.

Future monitoring approach: Nearly ten years of detailed and direct surveying of the activity data AC ratio and refrigerant charge make it possible to extrapolate the trends that have emerged over that time and to review them by complete and direct data collection only every three or four years. Therefore, we suggest discontinuing direct data collection from reporting year 2005 onwards, in favour of applying extrapolated AC ratios and refrigerant charges to official statistical data from KBA- and VDA. From 2011 onwards, a new monitoring approach has to be found which reflects phasing out of HFC-134a.

1.6.2. Air-Conditioning of Trucks

Application: Driver cabins of trucks are increasingly air-conditioned, although still on a much lower level than passenger cars. This mainly applies to the bulk of vehicles, namely light commercial vehicles. Only in heavy trucks (weight class above 7.5 t) a comparably high AC ratio exists. The EC-Directive on mobile air-conditioning currently provides for a review on the necessity of further use of the refrigerant HFC-134a, but does not yet propose a phase-out.

Present monitoring approach: Activity data are determined through a combination of official statistics, inquiries of truck makers, and extrapolations. The KBA annually publishes the number of new domestic registrations of trucks and tractors broken down into ten net weight categories that then, in a first step, are aggregated to three segments. For each of these segments typical truck models were selected, and the specific data on their AC ratio and refrigerant charges are inquired of manufacturers. These data are then extrapolated to all newly registered trucks. In ZSE, the existing refrigerant banks are available as time series in addition to average truck lifetimes and emission rates by weight categories. Emissions are calculated automatically after the new data have been entered into ZSE.

Future monitoring approach: The most time-consuming part of data collection, the inquiry of manufacturers about AC ratios and charges of typical truck models (VW: Transporter, LT, Caddy; DaimlerChrysler: Vito, Sprinter, Atego, Axor, Actros; Renault: Kangoo, Master) needs not to be carried out annually. It should be conducted in future in appropriate intervals in order to check up the extrapolation based on the empirical trend until 2004. Still the KBA-data on registration and the VDA-data on production will be used as reliable input material. As truck air-conditioning contributes only 0.8% to the emissions of key-source 2.F and 1.5% of the sub source "Refrigeration and Air-Conditioning", reduced data precision is acceptable.

1.6.3. Bus Air-Conditioning

Application: Buses are increasingly equipped with air-conditioning systems. Of the three bus categories (coaches, overland buses, city buses), coaches have already been 100% equipped since 1999. Overland buses (intercity buses) are approaching this penetration figure. However, half of the new city buses are not equipped with air-conditioners. The EC-Directive on mobile air-conditioning envisages a review of the necessity of the refrigerant HFC-134a for buses, but not yet its phase-out.

Present monitoring approach: Initial basis for annual estimation of activity data is the official KBA statistics on newly registered buses, which, however, are not broken down into the three categories. The quantitative composition of the three bus categories is included in the refrigerant model that has been developed with the help of the two leading German bus makers, Evobus (DaimlerChrysler) and MAN (together having a market share of 80-90%). It also contains average refrigerant charges, and estimated emission rates and bus lifetimes. As both the refrigerant model and the time series of the refrigerant bank are part of ZSE, only the experts from the two German bus makers have annually to be asked for AC ratios of their overland and city buses. Together with the public numbers on registration and production, these data are entered into ZSE for emissions calculation.

Future monitoring approach: In view of the low share of 0.8% in global warming key source emissions and of 1.5% in sub source emissions, longer intervals between direct data collection processes are feasible in this case, too. The trend of AC penetration until 2004 can be extrapolated to the next three years. After this period of time data on AC ratio should be checked through direct data collection, and the underlying refrigerant model (dating from 2002) should be thoroughly revised with support of experts.

1.6.4. Air-Conditioning of Agricultural Machines

Application: Since 1990, automobile machines in agriculture have increasingly been equipped with air-conditioning. Above all, tractors are numerically relevant, with 25,000 units being newly registered annually. These are joined by combines and chop-croppers, both being used only during the summer months. This source contributes only 0.04% to global warming emissions of key source 2.F.

Present monitoring approach: The KBA annually publishes only the number of newly registered tractors. Registrations of combines and chop-croppers are provided by sector experts and by companies. The sector experts also helped develop the refrigerant model, which is part of ZSE. It contains for the three categories of agricultural machines average refrigerant charges as well as specific emission rates. Experts are annually asked for estimates of AC ratios of newly registered agricultural machines (all categories). After data entering, ZSE calculates the annual HFC quantity increasing the domestic bank as well as the different kinds of emissions.

Future monitoring approach: We propose for a time of five years making use of the public statistics on tractors (registrations, number of manufactured units) as the only external input data, starting in the reporting year 2004. The remaining data such as refrigerant charges, AC ratios, and number of newly registered combines and chop-croppers should be extrapolated based on the trends of the five previous years. Emission rates can be left unchanged. Every five years activity data trends and emission rates should be revised with the support of sector experts.

1.6.5. Ship Air-Conditioning

Application: All inland passenger ships (not cargo ships) as well as all ocean-going passenger and cargo ships that have been built since 1998 have air-conditioning with HFC-134a. (This applies also to ships that are built at domestic shipyards.) Owing to their long lifetime (about 25 years), most existing ships still use ODS refrigerants.

Present monitoring approach: Considering the 0.02% contribution to emissions of key-source 2.F, data collection for this source requires too much effort, currently. It is true that AC ratios need not to be estimated for newly built ships as all ships have air-conditioning, so that a model of refrigerant charges by (six) ship categories, which has been developed with support of experts, is sufficiently detailed. But data surveying of all the new ships adding the German fleet differentiated by types, as well as of the number of newly built ships at German shipyards, is very time-consuming. The easily available statistics on the existing fleet (ocean going as well as inland) are of little use as AC systems in most existing ships still run with HCFC-22 refrigerant.

The numbers of new ships for the inland fleet are provided by Wasser- und Schifffahrts-Direktion Südwest, data on new ships for the ocean-going fleet are compiled by the Association of German Shipping Companies on request of Öko-Recherche. For data on new naval ships the Bundeswehr is addressed, for cruise liners a shipping company. Data on ships built at German shipyards are taken from the annual report of the Verband für Schiffbau und Meerestechnik.

After entering the new HFC-134a amounts into ZSE, which contains the necessary emission factors, emissions from production and from refrigerant banks are calculated.

Future monitoring approach: The authors of this study forecast a rise in emissions from roughly 2 t/y today to 6 t/y in 2020. This will be less than 0.1% of the key-source and of the sub source emissions. It is therefore proposed ceasing direct data collection for the time being, and estimating emissions through extrapolation based on the 1998 -2004 trends.

1.6.6. Rail-vehicle Air-Conditioning

Application: Since 1996, all new rail vehicles of the Deutsche Bahn AG and of smaller railway operators have been equipped with A/C systems. This applies also to regional trains and suburban trains. In addition, the Deutsche Bahn converted more than 3,000 A/C systems from R-12 to R-134a until 1998. Nearly all new trams and underground trains ("U-Bahn") have A/C systems. Despite the high AC ratio and the relatively high emission factor (EF=15%) air-conditioning in rail-vehicles is only a small emission source. The potential number of AC equipped rail-vehicles in Germany is limited to about 25,000 units (not considering locomotives), with one third already being air-conditioned with an average charge of 10-18 kg refrigerant per system. Rail vehicles account for 0.3% of the emissions of key-source 2.F, the proportion is not expected to increase significantly until 2020.

Present monitoring approach: With expert support, average refrigerant charges were determined for passenger-railcars, locomotives, suburban and underground trains, and trams. The amount of new refrigerant increasing the bank, which has to be entered into ZSE, is a result of the number of new minus decommissioned vehicles, multiplied by the specific refrigerant charges. Official statistics on the numbers of newly acquired and retired rail-vehicles are not available. Due to the large number of public and private railway companies as well as frequent restructuring within Deutsche Bahn, data collection is very time-consuming and uncertain.

Future monitoring approach: Considering the low share in key-source emissions, we suggest dispensing with annual complete data collection. It seems to be sufficiently reliable to extrapolate the annual number of rail vehicles acquired over the previous five years (2000-2004) in order to estimate the development of the HFC-134a bank in the next future. A revision should be carried out every five years through direct data collection the way it is practiced currently.

2. Foam Blowing (Rigid Foam) (2.F.2)

This sub source currently undergoes considerable changes. One component foam (OCF), which had been by far the largest single source before 2001, will nearly become irrelevant in the future, as the forthcoming EC-F-Gas-Regulation allows its use only in exceptional cases. In anticipation of this political measure, HFC emissions from OCF already decreased considerably in 2003, and this trend is expected to continue in 2004. At the same time, other single sources produce increasing emissions. In "Other PU rigid foam”, HFCs are in use on a large scale only from 2004 onwards, when the blowing agent HCFC-141b was banned. The sub source’s 2003 emission contribution of 13% to key-source 2.F, making it the third largest sub source, thus represents rather a snapshot than a long-term trend. As the future development can be predicted only with difficulty, the required data precision will not be deducted from the present share, which would classify the sub source as below the two-thirds threshold, but, in order to be on the safe side, it is suggested applying the highest possible data precision for the bulk of sub-source emissions.

2.1. PU One Component Foam (OCF)

Application: OCF is can-dispensed polyurethane foam with a gas mixture as propellant, which consists to a varying part of HFC-134a or HFC-152a. The application is considered open (EF=100%) as most of the propellant gas mixture escapes from the foam upon use, except for small residues that remain in the hardened foam for at most one year. From filling OCF cans in Germany, also domestic manufacturing emissions arise.

Present monitoring approach: Official statistics on OCF activity data are not available. With less than ten fillers located in Germany or supplying the domestic market from abroad, there is a high degree of mutual knowledge about the competitors, i.e. a high degree of market transparency. Therefore, as yet major companies or the Working Group of the OCF industry (AKPU) have been asked for the necessary data for emissions reporting: cans sold and cans filled in Germany, import, export, HFC-content per average-sized can, ratio of HFC-134a to HFC-152a, HFC emissions during filling. This approach corresponds to expert estimation according to tier 2.

Future monitoring approach: The EC F-Gas-Regulation envisages for HFCs in one-component foam a prohibition of placing on the market from 2008 onwards – "except when required to meet national safety standards". This implies that HFCs can be used also in the future in areas where hardly-inflammable propellants are required. Data collection on a low quantitative level will thus be necessary in the future, too. We propose maintaining estimation of activity data by sector experts. Direct reporting from the AKPU to the Federal Environmental Agency is desirable, but currently the working group is not willing to do so. Nonetheless, this approach should be tried again in the future. The UStatG ought to be used to collect data on HFC use for domestic OCF filling (see proposed questionnaire 10). These data could be used as primary data source or for crosschecking data obtained elsewhere (domestic filling, HFC composition).

2.2. XPS Insulating Foam

Application: Three of the four domestic producers of XPS insulating foam panels use HFCs. One producer uses HFC-134a, another uses HFC-152a, the third one uses both of them. As only two users for each HFC type exist, confidentiality issues arise. Therefore, data are surveyed by industry associations who report them anonymously to Öko-Recherche.

While HFC-152 almost completely emits upon production (EF=100%), in case of HFC-134a only a fraction of about 25% escapes to the atmosphere, with the larger part of the blowing agent remaining in the products. Thus, use-phase emissions have to be considered (EF=0.66%) during the lifetime of the XPS panels. Domestic HFC-134a bank in XPS foam increases annually by the amount of HFC-134a in newly produced but not exported insulation panels since 2001. (Import of HFC-134a containing panels is assumed zero).

Present monitoring approach: Overall HFC-152a consumption, which is equal to emission, is determined and entered into ZSE. Further, following data have to be surveyed amongst the users of HFC-134a: (1) annual HFC consumption, (2) emission rate on production, (3) import-export balance for insulation panels containing HFC-134a. Emissions from banked HFC-134a are calculated directly after entering the above named data into ZSE, which contains the constant emission factors and the time series of the HFC-134a bank. This method corresponds to tier 2.

Until reporting year 2002 the data was monitored and reported by FPX, the German Section of EXIBA (European Extruded Polystyrene Insulation Board Association), data as of 2003 were monitored and reported by APME (Association of Plastics Manufacturers in Europe), Brussels.

Future monitoring approach: The European Plastics Makers Association APME is willing to report data directly to the Federal Environmental Agency in the future, and to lay this down in a written agreement.

The UStatG can help to determine HFC-152a emissions by collecting consumption data (see proposed questionnaire 10). Data on HFC-134a surveyed via UStatG can be used for crosschecking of consumption data reported by APME. When doing so, confidentiality issues must be taken into consideration carefully.

2.3. PU Integral Skin

Application: HFCs are sometimes used as auxiliary blowing agents (1-2%) in the production of PU-integral skin products (shoe soles, bicycle seats, etc). HFC-134a and recently also HFC-365mfc (blended with HFC-227ea) and HFC-245fa are being used. As integral skin is open-cell foam, the blowing agent is released completely during the blowing process apart from a very small residue (EF=100%).

Present monitoring approach: The best source of data on domestic production in this small sector is chemical companies preparing and supplying specific foam formulations to be applied by foaming companies (end-users). Elastogran (subsidiary of BASF), the largest of suchlike companies in Germany, annually provides expert estimates on domestic HFC-consumption for this application to Öko-Recherche, since 1997.

Future monitoring approach: The Elastogran GmbH is willing to provide estimations on consumption of HFC types and amounts also in the future. At the same time, Elastogran shows little interest in laying down a written agreement on periodical reporting with the Federal Environmental Agency and refers to industry associations for this purpose. In the area of integral skin production, several associations exist, but the authors of this study experienced that they do not (yet) have the necessary knowledge about this special issue.

We therefore suggest for the Questionnaire 10 of the UStatG (use as propellant, blowing agent, etc) a further column "Integral skin" under the heading "Used Fluids as Blowing Agent in Manufacture of PU", which already contains proposed columns for OCF, XPS and other PU foams. Thus, annual data on consumption and emissions, differentiated by HFC types, could be surveyed directly. As long as this is not the case, expert estimation from Elastogran should be asked for further on.

2.4. Other PU Rigid Foam

Application: HFC blowing agents are to remain in the PU foam in order to increase the insulation performance. Emissions from finished products (bank emissions) take several decades. However, depending on the specific product, HFCs escape between 5 and 30% during the production (first year loss). In the three largest applications of PU rigid foam (household appliances, flexibly faced and rigidly faced insulating panels) only natural blowing agents are applied. Before 2004, in a number of further applications HCFC-141b was still used: firstly for small series block foam products with good insulation performance and high fire resistance, secondly for open applications on-site (mainly spray foam). Only since the use-prohibition of HCFCs from 2004 onwards, HFCs are used there on large scale: HFC-365mfc (for fire safety blended with HFC-227ea) and HFC-245fa.

Present monitoring approach: In 2002 and 2003, the new HFCs (365mfc and 245fa) were used only in small amounts for testing. The consumption data was directly surveyed of the only European producer of HFC-365mfc. Emissions assessment was based on rough estimates of manufacturing loss (EF=15%) and of HFC quantities banked in test products (EF=0.5%). From 1998 to 2003, most HFC blowing agent emissions arose from the use of HFC-134a in the production of sandwich panels at only one producer who was directly interviewed about his consumption and emission data. This producer converted to pentane as blowing agent in 2003 so that for the time being HFC-134a is only emitted from the bank built up over the five previous years, the emissions being calculated directly via ZSE.

Future monitoring approach: 2004 was the first year when the new HFCs (HFC-365mfc, HFC 245fa) were applied on a large scale as substitutes for HCFC-141b. The amended UStatG is considered an important means of surveying domestic HFC consumption. In the proposed Questionnaire 10 acc. to UStatG (use as propellant, blowing agent, etc), the application "Other PU Foam" should be addressed under the heading "Used Fluids as Blowing Agent in Manufacture of PU”, which offers further columns for OCF, XPS and Integral skin. Emission factors for production and banks must be determined differently. Their level varies strongly depending on the specific application. Therefore, a clear picture of the domestic use-channels is pre-conditioned. Such a picture, however, is currently not yet available.

For this purpose we suggest to the Umweltbundesamt an expert meeting with the main domestic users of HFCs for "Other PU rigid foams products". In such a meeting emission factors for production and banks could be established based on the expert knowledge about the specific applications spray foam, block foam, etc. In doing so also the various application-specific emission factors in the old and new IPCC Guidelines should be taken into consideration.

For the transition period we suggest asking those experts from companies and associations, who so far have been interviewed about HFC consumption and emission factors by Öko-Recherche.

3. Fire Extinguishers (2.F.3)

Application: For flooding of indoor spaces in case of fire HFC-227ea is used. Emissions occur during filling of fire extinguishing equipment in Germany and from banks, especially in case of fire alarm. For military applications also HFC-236fa is used, both in equipment and in open applications. HFC-23 has been approved, but not been used so far. Emissions from sub source 2.F.3 contribute only 0.05% to emissions of key-source 2.F; therefore rough estimates suffice. Nonetheless, the present monitoring system – in principle a "bottom-up tier 2" approach - should be maintained.

Present monitoring approach: Based on an agreement, the licensing authority in Freiberg reports all necessary data on HFC-236fa to the Federal Environmental Agency. Detailed data on consumption and emissions of HFC-227ea are annually reported to the Federal Environmental Agency by the company Kidde-Deugra, responsible for 95% of domestic sales. When entering into ZSE the remaining 5% are added.

Future monitoring approach: The precise and established existing approach should be maintained. Kidde-Deugra is willing to lay down a written agreement on reporting with the Federal Environmental Agency. Thus, it is not necessary to include fire extinguishers in questionnaire 10 according to amended UStatG.

4. Aerosols and Metered Dose Inhalers

This sub source accounted for roughly 6% of the emissions of key-source 2.F in 2003. The required data precision is lower than tier 2, which, however should be maintained – tier 2a for MDI and general aerosols, tier 2b for novelties.

4.1. Metered Dose Inhalers (MDI)

Application: HFC-134a and HFC-227ea are used as propellants in metered dose inhalers. Apart from minor emissions during filling in Germany, emissions from domestically used spray cans, which are openly applied (EF=100%), are of high importance. Emissions are completely assigned to the year in which the MDI units are sold (country-specific approach).

Present monitoring approach: Data on domestic sales differentiated by ingredients, package sizes, and HFC types are provided by experts from leading pharmaceutical companies. Data on consumed amounts and filling emissions are inquired of the national producers.

Future monitoring approach: If the national producers continue reporting their consumption data and associated filling emissions, this approach should be maintained. The amended UStatG (see proposed questionnaire 10) can be used complementarily or as an alternative data source (confidentiality!).

For estimation of emissions from domestic application, two possibilities exist: The market research company IMS Health, which is specialized on the pharmaceutical industry, offers delivery of such data to the Federal Environmental Agency. Costs involved would be EUR 1,000 (excl. VAT) for an analysis of amounts differentiated by pharmaceutical strength and package size, EUR 2,500 (excl. VAT) for further differentiation of data by products, which is deemed necessary for the calculation of the activity data "HFC-amount". Alternatively, data can be collected from experts at leading pharmaceutical companies as currently practiced.

4.2. General Aerosols

Application: General aerosols are all aerosols apart from metered dose inhalers and novelty aerosols: compressed-air sprays, freezer sprays, drain-pipe cleaning sprays, lubricant sprays, insecticide sprays, defence sprays. Emissions occur during filling and use. The application is open, as the gas is completely released on use.

Present monitoring approach: Experts from domestic fillers, who are members of the Association of the Aerosol Industry (IGA) within the Association of the Chemical Industry (VCI), supply annual estimations on the domestic HFC consumption as well as on the domestic market (consumption for filling plus imports minus exports). Additionally, data on domestic filling emissions are provided. According to IPCC-GL (2000) it is assumed that annual sales are used 50% (with HFCs being emitted) in the same calendar year they are sold, another 50% in the following calendar year.

Future monitoring approach: The Association of the Aerosol Industry (IGA) is willing to sign a written agreement with the Federal Environmental Agency on annual reporting on filling and sales data estimated by its member companies.

The consumption for domestic filling can be collected via UStatG (see proposed questionnaire 10) for crosschecking or for direct use in emissions determination.

4.3. Novelties

Application: These sprays with HFC propellants are partly decoration aerosols and partly pure entertainment products, e.g. silly strings for parties. HFC-134a is used as hardly inflammable propellant. As all novelties on the market are imported, domestic emissions arise only upon use.

Present monitoring approach: Data on total domestic HFC sales are taken from an EU-15 survey conducted by the European Aerosol Federation (Fédération Européenne des Aérosols - FEA) in 2002. The German share in the total EU amount was estimated by Öko-Recherche together with the German Aerosol Association (IGA) and additionally checked for plausibility by a major German importer. Pursuant to IPCC-GL (2000), use of the products and thus emissions are assumed to occur half in the year of the can sales, the remaining half in the following year, i.e. complete emission is assumed one year after the import of those products, at the latest.

Future monitoring approach: According to the forthcoming EU F-Gas-Regulation (Art. 8), there is a market prohibition for HFCs in novelty aerosols starting two years after coming into force of the law. This will probably be the case in 2008. For the time being, data should be estimated following the existing approach, i.e. with the help of IGA, who is willing to do so. New data from FEA if there will be any can be taken into consideration. As 100% of novelty aerosol sales to the domestic market are imported, the UStatG cannot contribute to data collection.

5. Solvents (2.F.5)

Solvents are by far the smallest sub source of key-source 2.F. Emissions amount to much less than 3 t/y, contributing less than 0.02% to key-source emissions. Thus, rough estimates are sufficient for emissions determination. The currently applied tier 2b approach should be maintained.

Application: HFC-43-10mee and HFC-365mfc are used as liquid substitutes for HCFC-141b in cleaning of sensitive surfaces. In 2005, only a few kilograms of HFC-365mfc were used. Due to legal restrictions (use allowed only for exceptional cases) the market potential of HFC-43-10mee, which is produced abroad, is quite small.

Present monitoring approach: Sales data of HFC-43-10mee are collected from the only importer and supplier in Germany. The information is to be kept confidential. According to IPCC GL (2000), emissions are considered equal to sales (=consumption). Annual sales are assumed to emit 50% in the same year and another 50% in the following year.

Future monitoring approach: The only supplier of HFC-43-10mee is ready to annually report in written form to the Federal Environmental Agency. In order to reduce time and effort of reporting, the interval between two reports should be expanded from one to three years, as long as no significant market changes occur. As long as the amounts remain so insignificant, there is no need to include solvents in the questionnaire 10 according to the amended UStatG.

6. Semiconductor Manufacture (2.F.6)

Emissions from the semiconductor industry contribute 3.2% to emissions of the key-source 2.F. Therefore, high data precision in reporting is not required. Nevertheless, a tier 2c approach according to IPCC GL (2000) has been applied so far. It is suggested that this precision level is maintained.

Application: Currently PFCs (CF_4, C_2F_6, C_3F_8, c-C_4F_8), HFC (CHF_3), nitrogen trifluoride (NF_3) and SF_6 are used for plasma etching of thin films and for cleaning of vapour deposition (CVD) tool chambers. (NF_3 is not yet subject to UNFCCC reporting requirements).

Present monitoring approach: Emissions cannot simply be derived from used quantities (sales of gas distributors), which in turn might be obtained from gas suppliers or via UStatG. Two factors determine how much of the F-gas input is released to the atmosphere unaltered, and thus contribute to global warming. The first is the utilisation removal efficiency of PFC transformation in the plasma chamber. The second is the prevalence and efficiency of downstream exhaust-gas treatment systems to destroy that fraction of the PFCs that remains untransformed in the plasma or recombines again after. The degree to which manufacturing plants are equipped with downstream emission control systems varies so that emissions can only be determined with sufficient accuracy at the level of individual plants ("fabs").

Emissions determination through continuous measurements is generally not considered feasible. The individual manufacturers are inquired about production capacity, gas quantities applied, and waste gas abatement systems installed. With a standardized calculation formula, emissions from each site are calculated (tier 2) by individual F-gas types, and then aggregated to total national amounts. Until 2000 (reporting year) this was carried out by EECA-ESIA (European Electronic Component Manufacturers Association – European Semiconductor Industry Association). Since 2001 data have been collected, evaluated and reported to the Federal Environmental Agency by the manufacturers association ZVEI (Components Division), based on a voluntary agreement. This will be continued until 2010 based on the new voluntary agreement, which has come into force mid-2005.

Future monitoring approach: Direct reporting of national emissions by ZVEI to the Federal Environmental Agency (UBA) should be maintained. Neither basic data of calculation (F-gas consumption, exhaust gas systems saturation rate) nor plant-specific emissions are open to the public. They are not even reported to the UBA, although they can be made available to them for reviewing on special request. Since only emissions are reported, but not the consumption they are based on, outsiders are not able to judge the real efforts of the semiconductor industry to reduce emissions.

In principle, collection of consumption data could by carried out via the UStatG. This approach is not suggested, as the consumption gives no indication of emitted amounts.

Supplementary Note on CF_4 in Manufacturing of Printed Circuit Boards

There is an intentional use of CF_4 in electronics as plasma etching gas, namely for desmearing in printed circuit board manufacturing. The consumption has remained constant for many years at about 2-2.5 t/y (metric tonnes). An emission factor of 85%

is applied to CF_4 consumption. For reporting, the resulting emissions (1.3 kt CO_2 equiv.) are added to the CF_4 emissions from semiconductor manufacturing.

So far, this amount has been estimated regularly both by sector experts and by gas suppliers. Due to the low share in key-source emissions of 0.01%, estimations by gas-suppliers are deemed sufficient in the future. We suggest extrapolation of 2000-2005 consumption and emission quantities to the next years. Every three years (at the latest), sector experts (see UBA-Report 15/05) should be asked for possible changes regarding this marginal emission source.

7. Equipment for T&D of Electricity (2.F.7)

This sub source accounts for only 6% of 2.F key-source emissions. Although data precision requirements are not rigorous, data precision in this application is probably the highest at all amongst the various sources within key-source 2.F (tier 3b with elements of tier 2a, according to IPCC-GL 2000). This high level can and should be kept in the future.

Application: SF_6 is used for insulation in equipment for transmission and distribution of power in high and medium voltage. Emissions occur during manufacturing and commissioning of equipment, during operation (including maintenance) from banks, and during disposal at end of equipment life.

Present monitoring approach: Based on a voluntary commitment the trade association ZVEI has been collecting data on SF_6 consumption as well as SF_6 emissions from manufacturing since 1997. For the largest part of emissions, this is done using a mass-balance approach. Moreover, in medium voltage ZVEI maintains the national data on the SF_6 bank (balance between newly installed and retired equipment), so that they are able to calculate use-phase emissions from medium voltage equipment, using a constant emission factor. In high voltage, both SF_6 bank and operating emissions are regularly surveyed amongst the domestic grid operators, by their association VDN. Upon decommissioning disposal emissions arise, which are also estimated by applying constant emission factors. Annually, ZVEI and VDN jointly report the data to the Federal Environmental Agency (UBA) and to Öko-Recherche.

Future monitoring approach: Annual reporting to UBA based on the 2005 revised and broadened voluntary self-commitment by ZVEI, VDN, VIK (Federation of Industrial Consumers and Self-producers = industrial operators) and Solvay. In contrast to the previous commitment, the 2005 version covers not only switchgear equipment but also components like instrument transformers and bushings.

In future, the UStatG may be of some complementary use through its annually conducted inquiry of gas dealers about their sales channels, according to the questionnaire 10-51. This questionnaire asks for SF_6 deliveries to manufacturers and to utilities so that it can partially be used to control their indications on consumption and on refills, respectively (see proposed questionnaire 10-51, industrial sectors: Electrical Industry and Electric Utilities).

8. Other SF_6-Appications (2.F.8)

This sub source is very heterogeneous and will undergo considerable change in the future. Some of its individual sub sources are subject to use-prohibitions by the forthcoming EC-F-Gas-Regulation (car tires, sport shoe soles, soundproof glazing). In one application, power capacitors, production will cease. Consumption is expected to remain constant in case of particle accelerators, tracer gas, and military radar. Despite these developments, this sub source currently and in future contributes significantly to domestic global warming emissions. In 2003, the sub source accounted for 18% emissions of key-source 2.F, which amounted to 10.9 million t CO_2 equiv. Other SF_6-applications is thus the second-largest sub source after "Refrigeration and Air-Conditioning” (54%).

This fact does hardly affect data precision. IPCC-GL (2000) offers for each of the individual sources within sub source 2.F.8 only one tier, which can be met – at least in Germany – without difficulty. According to 2003 emission data, the source "soundproof glazing" accounts for nearly 60% of total sub source emissions, and, despite the EC-F-Gas-Regulation, this proportion is going to rise in the future. For, even if manufacturing ceases, the bulk of emissions occur upon decommissioning after a lifetime of 25 years. By 2020, emissions from soundproof glazing will have tripled due to disposal emissions, and the share of this source in overall sub source emissions will have increased to over 90%. Therefore, emissions from soundproof glazing are given high priority within the sub source 2.F.8.

8.1. Soundproof Glazing

Application: SF_6 is filled in the pane interspace of double glazing windows in order to improve the sound insulating effect. Emissions occur on production, during use, and on disposal. The EC-F-Gas-Regulation provides for a use prohibition, i.e. emissions from production will no longer occur from 2006 and 2007 onwards, while emissions from use and disposal continue arising for more than two decades.

Present monitoring approach: Consumption for manufacturing is surveyed of gas suppliers, annually. This figure is reduced by 33% in order to account for filling emissions, and then entered into ZSE where it is added to the bank. As in ZSE the time series of the SF_6 bank accumulation is available as of 1975, the new amount of the bank as well as the bank emissions (EF=1%) are generated automatically. At the same time, disposal emissions are calculated from the consumption dating 25 years back. The disposal EF is 100% because SF_6 is not recovered from windowpanes.

Future monitoring approach: After installation of ZSE, every year only the consumption figure must be determined and entered there. There is not much to be changed. However, collection of consumption data can now be carried out through UStatG (proposed questionnaire 10-51, sector "producers of windowpanes and windows - insulating gas") as part of the official survey amongst gas suppliers. After 2010 (at the latest), this survey can cease or be used to control the use prohibition. Emissions from bank and from disposal, which continue in the future, will be generated further on by ZSE.

8.2. Car Tires

Application: Thanks to the large size of molecules, SF_6 in tires allows for longer pressure stability than air as long as there is no mechanical damage. Emissions occur during disposal when tires are changed, which usually happens three years after filling. Then, the gas is completely (EF=100%) released to the atmosphere.

Present monitoring approach: Annual new gas consumption is surveyed of gas dealers (sales to tire traders, etc). Disposal emissions of a specific reporting year equal the consumption three years before.

Future monitoring approach: Survey of consumption for filling through amended UStatG (gas suppliers to tire traders, same questionnaire as above, sector "repair shops, tire traders"). The EC-F-Gas-Regulation bans the use of SF_6 in car tires as of 2006 (or 2007). Due to the time interval of three years between filling and emission, emissions from disposal will occur until 2009 (or 2010). It is suggested going on with monitoring until 2010 in order to check whether the use prohibition is observed.

8.3. Military Aircraft Radar

For confidentiality, emissions from this source are reported together with emissions from another single source.

Application: SF_6 is used as an insulating medium in the radar systems of the AWACS planes of the NAEWF (NATO Airborne Early Warning Force). Its purpose is to prevent electric flashovers. In order to balance the pressure when taking off, SF_6 is released on purpose to the atmosphere and needs to be refilled again from an on-board gas container when flying down.

Present monitoring approach: Annually, gas traders are asked for consumption data that are crosschecked with the data obtained from users. Calculation of emissions (EF=100%) is based on a percentage (confidential) representing the share of emissions which are attributable to Germany. This share is contained in ZSE.

Future monitoring approach: Survey of consumption data via UStatG from gas dealers (proposed questionnaire 10-51, sector "military, armed forces – military purposes"). Calculation of emissions is carried out by ZSE, after consumption data are entered. The new IPCC-Guidelines (2006) contain provisions for this application for the first time. These provisions are consistent with the German approach.

8.4. Glass Fibres

This SF_6 application became known to national monitoring agency only in 2004. There are no provisions available for the calculation of emissions. Alternatively, the default emission factor valid in semiconductor manufacture (EF = 85% of annual consumption) is used.

Present monitoring approach: Consumption data are provided by gas trade.

Future monitoring approach: Consumption will be surveyed of gas suppliers also in the future, but can use questionnaire 10-51 ("Miscellaneous") according to UStatG.

8.5. Particle Accelerators

Application: SF_6 is used as insulating gas in particle accelerators. Emissions occur during production, from banks, and on disposal. Currently, provisions for emissions estimation are under way as part of the new IPCC-Guidelines, which rely on the German approach.

Present monitoring approach: In 2004, Öko-Recherche conducted a special survey with the aim of updating 1999 data. For this survey, both users and manufacturers were asked for SF_6 charges, gas consumption, new equipment, and equipment taken out of operation. Five application areas of particle accelerators were found. Emission rates for first filling and for disposal are oriented at typical values in comparable electrical equipment. The much more important use-phase emissions were established by surveying annual gas refills of operators of particle accelerators.

Future monitoring approach: Reliable determination of consumption for initial fill and subsequent topping up is not feasible via UStatG, as gas suppliers cannot clearly distinguish sales to this specific application from sales to their customer group research institutions or "electrical industry" (see proposed questionnaire 10-51). Furthermore, differentiation between initial fill and refill of SF_6 is not provided for under UStatG. We suggest that the consumption and emission data from the special Öko-Recherche survey (UBA Text 15/05), which has become part of ZSE, are extrapolated to the future. Reviewing surveys should be carried out every five years in order to account for changes in the application. This approach is deemed sufficing, the more so as the application is one of the smaller sources (1.1% of key-source 2.F emissions, 6% of sub source 2.F.8), for which rough estimates are acceptable.

8.6. Power Capacitors

Application: SF_6 is used in an open process for gas impregnation of components of power capacitors. Consumption is emitted completely on manufacturing (EF=100%).

Present monitoring approach: Consumption data have been reported to Öko-Recherche by ZVEI since 2003. A recalculation has been carried out back to 1995.

Future monitoring approach: The ZVEI is willing to collect the consumption data also in the future, and to report them directly to the Federal Environmental Agency. We expect that SF_6 is no longer used for this application after 2006. As emissions occur only during production and no gas is banked in finished products, from 2007 onwards, emissions will only arise during the production of spare parts. Inclusion of this application in the data survey pursuant to UStatG is not deemed necessary as data continue to be reliably surveyed and reported by ZVEI. In addition to that, gas dealers could distinguish sales to this specific application only with difficulty from sales to manufacturers of electrical equipment for power transmission and -distribution.

8.7. Sport Shoe Soles

For confidentiality reasons emissions from this source are reported together with emissions from another single source.

Application: SF_6 is used in sport shoe soles to ensure an elastic attenuation of shocks when the foot touches ground. All sport shoes containing SF_6 are imported. The gas is emitted completely upon disposal (EF=100%). A time interval of three years between sale and disposal are assumed.

Present monitoring approach: Information on annual amount of SF_6 imported to Germany in shoe soles is provided by the only manufacturer, Nike, who communicates the EU-wide figure. 25% of this figure is assigned to Germany. As the time series for the SF_6 bank in sport shoes is contained in ZSE, the new SF_6 quantity adding to the bank in year n is calculated to equal disposal emissions in year n+3.

Future monitoring approach: The EC-F-Gas-Regulation forbids placing on the market of SF_6-filled sport shoe soles as of 01.07.2006. Pursuant to a self-commitment, Nike has not used SF_6 in new sport shoes since 2003, but uses PFC-218 for a certain number of shoe soles instead. SF_6 emissions occurring until 2006 due to the time interval between sale and disposal are directly generated by ZSE.

Regarding monitoring of the transitional PFC emissions following proposal is given: Between 2003 and 2006 Nike uses PFC-218 instead of SF_6 for a certain part of its shoe soles, and stops using greenhouse gases afterwards. Emissions from these shoes will occur between 2007 and 2009. They will be negligible in relation to the emissions of the key-source 2.F as well as of the sub source 2.F.8. Thus, rough estimates will be sufficient.

8.8. Tracer Gas

Application: As SF_6 is a trace gas that is both stable and readily detectable even in extremely low concentrations, it is used to study ground level and atmospheric airflows and gas dispersal. Its application is open, with consumption being emitted completely (EF=100%).

Present monitoring approach: Consumption data is collected from experts from the six most important research institutes that carry out tracer gas investigations. These institutes are addressed every three or four years, as consumption has been stable since 1996.

Future monitoring approach: High data precision is not required for this small source. Consumption cannot be surveyed by UStatG, as gas dealers cannot clearly identify sales to this specific application (confusion with sales to users of particle accelerators). It is therefore suggested that the consumption trend of the last years, which is entered in ZSE as time series, is extrapolated to the future. Every five years experts should be asked for new estimates in order to check the data trend.

Part II
Emission Data 1999-2003 and
Emission Forecast for 2010 and 2020

Objective: Updating and Forecasting Emissions

Part II of this research report is independent from part I. Here, the point is not to propose a new emissions monitoring system for future use. Yet, part II entirely relies on the hitherto existing methods of data collection.

The first chapter recapitulates historic emission data of from 1999 to 2003. This takes place in section I in a condensed version because these data have already been entered into ZSE and Germany's international emissions reporting. In addition to that, their origin is already documented at length in a study for the Umweltbundesamt, which was being prepared at the same time[4]. Therefore, only the data sources for 2003 that have been used for the first time are documented in detail – in section II.

The second chapter presents emission projections for 2010 and 2020, which likewise are part of Germany's international reporting obligations. The forecasting on its part is empirically based on the historic emissions of from 1995 to 2003, which were estimated under the terms of the old monitoring system. In the two reference years 2010 and 2020 each individual projection follows four different emission scenarios the underlying assumptions of which are described in detail.

Methodological Remark on Classification by Substance-Groups

Unlike part I, part II of this report does not divide F-gas emissions into three emission sources 2.C, 2.E, 2.F (Metal production, Production of Halocarbons, Consumption of F-gases) and into their sub sources, but into the three substance-groups HFCs, PFCs, and SF_6. The latter is not only the conventional classification in Germany since 1996, which we assume to provide a higher degree of clarity when surveying emissions. Besides, this classification is also used in CRF tables: in Table10s4 exclusively, and in Table2(II)s1 and Table 2(II)s2 in combination with the classification by emission sources.

[4] This study completed by Winfried Schwarz for the German Umweltbundesamt by June 2004 is called "Emissions, Activity Data, and Emission Factors of Fluorinated Greenhouse Gases (F-Gases) in Germany 1995-2002 - Adaptation to the Requirements of International Reporting und Implementation of Data into the Centralised System of Emissions (ZSE)". It was released 2005 as UBA-Text 15/05, and can be downloaded from http://www.umweltbundesamt.org/fpdf-l/2903.pdf. In this study it is cited as "UBA-Text 15/05".

First Chapter. Emission Data until 2003

It was an objective of this study to establish annual emissions of fluorinated gases for the reporting years 1999-2003. In March 2003 the historic figures of 1999 to 2001 were communicated to the Umweltbundesamt (1st interim report). A further interim report presented the respective figures for 2002, in August 2003. Finally, the fourth interim report from February 2005 contains all emission data for the 1999-2003 periods.

This final report has integrated all findings of the preceding interim reports after intensive reviewing and several corrections. Insofar, it is the updated version.

As is known, at the end of every year the data on emissions of substances with climate impact have to be reported to the EU in specified sector classification, for the previous year. By 15th of April of the subsequent year these emission data must be forwarded to UNFCCC secretariat, too. Both submissions follow specified formats for reporting (Common Reporting Format = CRF) in accordance with the UNFCCC reporting guidelines (FCCC/CP/1999/7).

In section I of this chapter of this final report F-gas emissions of 1995, 1998, 2000, 2002, and 2003 are shown again in an abbreviated version. All presented figures have already been entered into the Centralised Systems of Emissions (ZSE) and have already been used for international reporting. For clarity, the emission year 2004 is out of the scope of this study and will be monitored and reported separately.

Detailed documentation of the above mentioned emissions data may remain undone not least of all because the way of annual emissions data collection has been described in extenso for altogether forty F-gas applications in the simultaneous Umweltbundesamt study for the years 1995 to 2002, which is indicated on the previous page as "UBA-Text 15/05". Readers with deeper interest in German F-gas emission data are encouraged to make use of it.

While the method of emission data collection is the same for 2003 as for the - well-documented - 1995-2002 period, and the emission factors were not changed to a noteworthy extent in 2003 against the time before[5], most activity data had to be updated for the reporting year 2003.

Section II of this first chapter delivers the missing data sources for the 2003 emissions that were estimated in 2004. For practical reasons all the data that were used the first time in 2003 for the reporting year 2002 are documented in addition.

[5] One very important exemption is the altered disposal emission factor for end-of-life equipment in all sectors of refrigeration and air-conditioning. It was changed from 25% to 30% which is the default level in the IPCC Good Practice Guidance from 2000. The previously used "country-specific" 25% had been based on the assumption that German end-of-life recovery was better than on international average. This may be or may not be the case. The point is that up to now no empirical survey of the German end-of-life refrigerant recovery has been carried out that proofs such higher recovery efficiency. From a methodological perspective a national disposal emission factor lower than usual is not justified.

I. Emissions from 1999 to 2003 (Abbreviated Version)

Over the 1995-2003 period, overall emissions of the greenhouse gases HFCs, PFCs, and SF_6 increased from 3,237 t to 6,837 t. Unlike the unweighted emissions, the GWP-weighted emissions decreased over the same time from 15.64 to 13.69 million t CO_2 equivalent. Behind these contrasting figures are different trends, which make it necessary to look closer at the individual groups of gases.

1. HFCs 1995-2003

Since 1990/1995[6] emissions of fluorinated gases have developed diversely in the three substance groups. First we look at HFCs.

Table 3: HFC-Emissions [t] 1995-2003					
	1995	**1998**	**2000**	**2002**	**2003**
Stationary Refrigeration/AC	73	516	854	1,155	1,339
Mobile Refrigeration/AC	170	677	1,168	1,653	1,908
- thereof passenger cars	*133*	*563*	*988*	*1,405*	*1,616*
PU One-Component Foam	1,823	1,844	1475	897	894
PU-Foam (Hard + Integral)	0	92	94	118	126
XPS-Foam	0	0	0	1,971	1,709
Metered Dose Inhalers	0	27	84	201	205
Other Aerosols/Solvents	254	262	269	274	274
Fire Extinguishers + Other	1.0	1.0	2.0	2.5	3.0
Subtotal (Use)	**2,319**	**3,419**	**3,946**	**6,273**	**6,459**
Other (Production, etc)	360	259	128	132	74
Total	**2,679**	**3,678**	**4,073**	**6,404**	**6,532**

Table 4: HFC-Emissions [million t CO_2 equivalent] 1995-2003					
	1995	**1998**	**2000**	**2002**	**2003**
Stationary Refrigeration/AC	0.169	1.170	1.994	2.758	3.205
Mobile Refrigeration/AC	0.234	0.915	1.571	2.218	2.567
- thereof passenger cars	*0.172*	*0.732*	*1.284*	*1.826*	*2.101*
PU One-Component Foam	1.534	1.553	1.084	0.662	0.587
PU-Foam (Hard + Integral)	0	0.12	0.123	0.148	0.158
XPS-Foam	0	0	0	0.906	0.698
Metered Dose Inhalers	0	0.035	0.168	0.326	0.318
Other Aerosols/Solvents	0.318	0.329	0.336	0.339	0.339
Fire Extinguishers + Other	0.012	0.012	0.019	0.017	0.022
Subtotal (Use)	**2.267**	**4.133**	**5.294**	**7.374**	**7.894**
Other (Production, etc)	4.212	2.833	1.207	1.212	0.533
Total	**6.479**	**6.966**	**6.501**	**8.586**	**8.427**

[6] In 1990, there was not yet targeted manufacture or application of HFCs. Emissions attributable to the year 1990 exclusively came from production of HCFC-22, which generates HFC-23 as a by-product. Therefore, in this report F-gas emission figures are not given before 1995. For F-gas emissions in 1990, see part III of this report.

In terms of mass, overall HFC emissions increased from 2,679 t to 6,532 t over the 1995- 2003 period. However, from 1995 onwards their climate impact (in terms of CO_2 equivalents) grew substantially slower - from 6.5 to 8.4 million t CO_2 equivalent. On the one hand, HFC emissions from deliberate use went up steeply as of 1995 from 2.3 to 7.9 million t CO_2 equivalent; this trend continues. As Tables 3 and 4 show, it is most marked in sectors that apply refrigerants, which is to say in stationary and mobile refrigeration and air conditioning. Further, global warming emissions increased, although on a lower level, from XPS foaming and from MDIs.

On the other hand, there was a substantial decrease in HFC emissions from one-component foam application at the same time, at least from 2000 onwards. This application had met with strong criticism in public. The 1995-2003 drop in unintentional emissions from halocarbon production was much greater. HCFC-22 manufacturers succeeded in cutting by-product emissions of the potent greenhouse gas HFC-23 from a very high initial level of almost 4 million t CO_2 equivalent down to approx. 0.45 million t. This corresponds to a reduction of almost 90%.

2. PFCs 1995-2003

Since 1995, owing to industry efforts emissions of PFCs continue sinking – both in terms of mass and of global warming impact. This is shown in Tables 5 and 6.

Table 5: PFC-Emissions [t] 1995-2003

	1995	1998	2000	2002	2003
Aluminium Production	230	173	53	64	70
Semiconductor Manufacture	23	29	43	33	34
Printed Circuit Boards	2	2	2	2	2
Refrigeration	1.2	7.8	11.6	13.7	14.7
Total	**256**	**212**	**110**	**112**	**121**

Table 6: PFC-Emissions [million t CO_2 equivalent] 1995-2003

	1995	1998	2000	2002	2003
Aluminium Production	1.552	1.166	0.356	0.431	0.475
Semiconductor Manufacture	0.177	0.238	0.333	0.250	0.260
Printed Circuit Boards	0.013	0.013	0.013	0.013	0.013
Refrigeration	0.008	0.056	0.084	0.101	0.108
Total	**1.750**	**1.473**	**0.786**	**0.795**	**0.856**

Both the producers of primary aluminium and the semiconductor manufacturers have entered into self-commitments not only on annual monitoring of emissions but also on reducing emissions below the baseline level. Aluminium industry has dropped their emissions absolutely, in semiconductor manufacturing the strong emission growth that was feared has failed to occur.

In 2003, PFC emissions figured half the 1995 level. They had decreased from 256 t to 121 t or from 1.75 to 0.86 million t CO_2 equivalent.

3. SF_6 1995-2003

Over the 1995-2003 period, SF_6 emissions decreased from 303 to 184 t, which is a reduction in CO_2 equivalent emissions from 7.2 to 4.4 million tonnes. This is shown in Tables 7 and 8.

Tab. 7: SF_6-Emissions [t] 1995-2003					
	1995	**1998**	**2000**	**2002**	**2003**
Electricity T&D Equipment	43.4	38.7	30.4	30.7	26.3
Other Electr. Applications	5.2	17.0	18.4	13.8	10.9
Magnesium Casting	7.7	9.2	13.2	16.0	19.1
Soundproof Glazing	107.9	56.5	51.7	46.4	48.3
Car Tires	110.0	125	50	9	6
Soles/AWACS/Fibre Optics	18.5	22.3	23.3	16.6	15.4
Tracer Gas/Al-Cleaning	1.0	1.0	14.5	35.5	45.5
Other	9	11.4	11.4	12.4	12.6
Total	**303**	**281**	**213**	**180**	**184**

Tab. 8: SF_6-Emissions [million t CO_2 equivalent] 1995-2003					
	1995	**1998**	**2000**	**2002**	**2003**
Electricity T&D Equipment	1.036	0.924	0.727	0.733	0.629
Other Electr. Applications	0.125	0.405	0.441	0.329	0.260
Magnesium Casting	0.185	0.220	0.316	0.383	0.457
Soundproof Glazing	2.578	1.350	1.236	1.108	1.155
Car Tires	2.629	2.988	1.195	0.215	0.143
Soles/AWACS/Fibre Optics	0.442	0.532	0.557	0.396	0.369
Tracer Gas/Al-Cleaning	0.024	0.024	0.347	0.848	1.087
Other	0.216	0.273	0.271	0.295	0.301
Total	**7.235**	**6.718**	**5.090**	**4.308**	**4.402**

In the first instance, the reduction is a result of a practical SF_6 phase-out in car tires, an application that already in the nineties had caused general astonishment outside Germany. In this case successful environmental education gave rise to emission reduction of more than 100 t, which is in terms of global warming 2.5 million t CO_2 equivalent. Similar applies to soundproof glazing where SF_6 has been cut to a tenth of its former level of annual consumption, since 1995. Present and future emissions predominantly come from end-of-life treatment of old panes when SF_6 is simply released to the atmosphere. It is worth noting that also emissions from manufacture of equipment for power transmission and distribution have fallen 40%. In this sector a voluntary agreement on monitoring and reducing emissions exists.

There are, however, opposite tendencies. In 1998, secondary aluminium smelters started using SF_6 as a cleaning gas in huge amounts although SF_6 had been completely phased out from this application the years before. Almost 1 million t CO_2 equivalent emissions have been added this way. Continuous increase must also be stated for the use of SF_6 as a cover gas in magnesium casting. While the forthcoming EU legislation provides for SF_6 phase-out in magnesium foundries, for aluminium foundries there is no legal solution in sight now.

II. Data Sources for 2002 and 2003 Emissions

Documentation of data sources follows the division of F-gases into the three substance groups HFCs, PFCs, and SF_6. Generally, the sequence of sectors follows the order in the aforementioned study "Emissions, Activity Data, and Emission Factors of Fluorinated Greenhouse Gases (F-Gases) in Germany 1995-2002." (UBA-Text 15/05). There, forty fields of application are described as "F-gas-sheets".

In order to make to the reader this structure compatible with the CRF arrangement by emission sources, the CRF specific sector numbers are added in brackets to the titles of the individual sectors.

This published version of the report does not give information on personal phone numbers and e-mail-addresses.

Refrigeration and Air Conditioning Equipment (2.F.1)

Refrigerated Vehicles (2.F.1)

Kraftfahrt-Bundesamt (Federal Office for Motor Vehicles), Statistische Mitteilungen, Reihe 3: Kraftfahrzeuge, Neuzulassungen – Besitzumschreibungen - Löschungen von Kraftfahrzeugen und Kraftfahrzeuganhängern, Jahresband 2002 und 2003, Übersichten 19 und 32. Appears in print and pdf not before the end of the following year. Pre-printed in September by VDA (Verband der Automobilindustrie), Facts and Figures, Frankfurt am Main.

Harnisch, J., et al.: Risks and Benefits of Fluorinated Greenhouse Gases in Techniques and Products under Special Consideration of the Properties Intrinsic to the Substance, Research Report 201 64 315, UBA-FB 000673, Climate Change 03/04, on behalf of the Umweltbundesamt, Berlin, June 2004, also available on http://www.umweltbundesamt.de.

Refrigerated Containers (2.F.1)

Yves Wild, Kühlcontainer und CA-Technik, in: Gesamtverband der Deutschen Versicherungswirtschaft (GDV), Berlin 2003: www.containerhandbuch. Darin www.containerhandbuch.de/chb/wild/index.html.

Global reefer output soars, Issue: January 2004, www.worldcargonews.com/htm/nf20040115.971192.htm

Domestic Heat Pumps (2.F.1)

Bundesverband WärmePumpe (BWP) e. V., München, Entwicklung des deutschen Wärmepumpen-Marktes, Stand 03/2003, Wärmepumpen-Absatz 2002. http://www.waermepumpe-bwp.de/nonflash/frames/aktu/dokk.htm

Bundesverband WärmePumpe (BWP) e. V., Wärmepumpen erfreuen sich steigender Beliebtheit, 14.11.2004, Wärmepumpen-Absatz 2003. http://www.waermepumpe-bwp.de/content/statistik-h.jpg

Household Refrigerators and Freezers (2.F.1)

Liebherr Machines Bulle S.A, Bulle (Switzerland), 0041-26-913-0. Jürgen Melzer, info@lmb.liebherr.com pers. comm. to ÖR, 05.03.04.

Greenpeace Deutschland, Hamburg, 040-30618-0.
Wolfgang Lohbeck (Head of Atmosphere Department), ongoing pers. comm. to ÖR.

Centralized Air Conditioning (Stationary) (2.F.1)

Solvay Fluor & Derivate GmbH, Hannover, 0511-857-0.
Christoph Meurer (Manager Technical Services Refrigerants): HFC chillers sold to the German market and key figures for the estimation of their lifetime, average capacities in kW and charge in kg/kW. Internal Compilation, 27.03.03.
Öko-Recherche/Solvay Fluor: Conference on basic data and sales quantities of HFCs for refrigeration and air conditioning. Participants: Winfried Schwarz (ÖR), Christoph Meurer (Solvay) and Felix Flohr (Solvay), Hannover, 26.03.03.
IKK 2003, Hannover, 10.10.2003, Conference with producers and importers on the development of the refrigerant market 2002 und 2003.

Room Air Conditioners (2.F.1)

Polenz Klimageräte GmbH, Norderstedt, 040-52140-0.
Jörn Kressner (Vertrieb Investitionsgüter/Technische Leitung), 10.10.03 (IKK-Hannover).
Daikin Airconditioning Germany GmbH, Unterhaching, 089-74427-0.
Achim Zeller (Manager Productmanagement), 16.10.03.
Daikin Europe Brussels Office, 0032-2-529-6106.
Achim Zeller (Senior Executive – New Business Section), 23.09.2004.
De'Longhi S.p.A., Treviso (Italia), 0039-0-422 4131.
Stefania Velo (Air Conditioning Dept.), 21. u. 23.01.04.

Industrial and Commercial Refrigeration (2.F.1)

Öko-Recherche/Solvay Fluor: Conference on basic data and sales quantities of HFCs for refrigeration and air conditioning. Participants: Winfried Schwarz (ÖR), Christoph Meurer (Solvay) and Felix Flohr (Solvay), Hannover, 26.03.03.
DuPont Deutschland GmbH, Bad Homburg, 06172-87-0.
Joachim Gerstel (Sales Manager Refrigerants), Comm. on sales of HFC-236fa as a refrigerant, IKK 2003, Hannover 10.10.03.
Mr Weisshaar, Weisshaar GmbH & Co. KG, Bad Salzuflen, 05222-9273-0.
Information on refrigerants for crane air conditioning, 14.10.03.
Refrigerant producers. Direct enquiries about sales quantities and perspectives of chlorine-free refrigerants for the use in stationary refrigeration and air conditioning, IKK 2003. Hannover, 10.10.2003: Karsten Schwennesen (Ineos Fluor International Ltd., Frankfurt), Joachim Gerstel (Du Pont Deutschland GmbH, Bad Homburg), Klaus Pesler (ATOFINA Deutschland GmbH, Düsseldorf), Hans-Jürgen Kemler (Westfalen AG, Münster), Ewald Preisegger and Christoph Meurer (Solvay Fluor und Derivate GmbH, Hannover).
ILK Dresden/FKW Hannover, Aktuelle TEWI-Betrachtung von Kälteanlagen mit HFKW- und PFKW-Kältemitteln unter Berücksichtigung der unterschiedlichen Rahmenbedingungen für verschiedene Anwendungsgebiete, im Auftrag des Forschungsrats Kältetechnik e.V., FKT 96/03, Frankfurt, November 2003.
André Siegel, Axima Refrigeration GmbH, Lindau, 08382-706-1, pers. comm. at the DKV meeting 2003 in Bonn, 21.11.03.
Haaf, Siegfried u. Pauls, Gerlef, Linde AG, Geschäftsbereich Linde Kältetechnik, Köln, 02236-601-0, Conference at Umweltbundesamt, Berlin, 25.06.03.

Passenger Car Air Conditioning (2.F.1)

Adam Opel AG, Rüsselsheim, 06142-77-0. Für 2002: Susanne Hartmann (Produkt-Kommunikation Deutschland), 05.09.03. für 2003: Sven Markurt (Presseabteilung), 09.07.04.
AUDI AG, Ingolstadt, 0841-89-0. Für 2002 + 2003: Günther Beham (Absatzplanung), 02.09.03 + 01.06.04.
BMW AG, München, 089-382-0. Für 2002 + 2003: Albrecht Jungk (Verkehr und Umwelt), 29.08.03 + 26.06.04.
Chrysler (DaimlerChrysler AG) Product Management Chrysler & Jeep, Berlin, 030-2694-0. Für 2002 + 2003: Julia Weber, 20.09.03 + 10.09.04.
Citroen Deutschland AG, Köln, 02203-44-0. Für 2002 + 2003: Heike Schäfer (Produktionsadministration), 12.09.03 + 10.08.04.
Daihatsu Deutschland GmbH, Tönisvorst, 02151-705-0. Für 2002 + 2003: R. Piotraschke (Produktplanung/Homologation), 26.09.03 + 07.09.04.
DaimlerChrysler AG, Stuttgart, 0711-17-0. Für 2002: Claudia Vogel (Environment Strategy PC & Region 3 - Japan), 01.10.03. Für 2003: Marko Borgwardt (Team Auftragsprognose GOP), 11.06.04.
Deutsche Renault AG, Brühl, 02232-73-0. Für 2002 + 2003: Angela Lehmann (Produktkommunikation), 23.10.03 + 08.06.04.
Dr. Ing. h.c. F. Porsche AG, Zuffenhausen, 0711-911-0. Für 2002 + 2003: Stefan Marschall (Öffentlichkeitsarbeit), 29.08.03 + 23.06.04.
Fiat-Automobil AG, Frankfurt, 069-66988-0. Für 2002+ 2003: Rosa Salvia, 28.08.03 + 15.06.04.
Ford Werke AG, Köln, 0221-90-0. Für 2002 + 2003: Hanns-Peter Bietenbeck (Senior Engineer Environmental Regulations), 22.09.03 + 15.06.04.
Honda Deutschland GmbH, Offenbach, 069-8309-0. Für 2002 + 2003: Peter Treutel (Produktplanung), 26.09.03 +.16.06.04.
Hyundai Motor Deutschland GmbH, Neckarsulm, 07132-487-0. Für 2002+ 2003: Uwe Wazal, (Kundendienstförderung), 18.09.03 + 14.06.04.
Kia Motors GmbH, Bremen, 0421-4181-0. Für 2002: Dörte Steffens (Presse-Öffentlichkeitsarbeit), 01.09.03. Für 2004: Hr. Döller, 31.08.04.
Land Rover Deutschland, Schwalbach Ts., 06196-9521-0. Für 2002+ 2003: Herr Buchhardt, 10.09.04.
Mazda Motors Deutschland, Leverkusen, 02173-943-0. Für 2002 + 2003: Matthias Brieden (Produktmarketing), 25.09.03 + 01.07.04.
Mitsubishi Motors Deutschland GmbH, Trebur, 06147-207-01. Für 2002+ 2003: Valeska Haaf (Produktmanagement), 02.09.03 + 08.06.04.
Peugeot Deutschland GmbH, Saarbrücken, 0681-879-0. Für 2002 + 2003: Christine Clavier (Neuwagenlogistik), 26.08.03 + 29.06.04.
Renault Nissan Deutschland AG, Brühl, 02232-57-0. Für 2002 + 2003: Hr. Schweitzer (Neuwagenvertrieb), 01.09.03 + 16.06.04.
Saab Deutschland, Bad Homburg, 06172-900-0. Für 2002 + 2003: Olaf H. Meidt (Presse- und Öffentlichkeitsarbeit), 29.08.03 + 08.06.04.
SEAT Deutschland GmbH, Mörfelden, 06105-208-0. Für 2002 + 2003: Burkhard Kolb (Neuwagen-Disposition), 29.08.03 + 27.05.04.
Skoda Deutschland, Weiterstadt, 06150-133-0. Für 2002 +2003: Eric Lehmann (Absatzplanung), 29.08.03 + 01.06.04.
Smart GmbH, Böblingen, 07031-90-0. Für 2002 + 2003: Markus Mainka, 29.08.03 + 16.06.04.
Subaru Deutschland, Friedberg, 06031-606-0. Für 2002 + 2003: Simone Vrba (Fahrzeugdisposition), 05.09.03 + 20.07.04.
Suzuki International Europe GmbH, Bensheim, 06251-5700-0 (Suzuki Auto GmbH, Oberschleißheim, 089-31563-0). Für 2002 + 2003: Michael Rist, 10.09.03 + 01.06.04.
Toyota Deutschland, Köln, 02234-102-0. Für 2002 + 2003: Michael Nordmann, 01.09.03 + 08.06.04

Volkswagen AG, Wolfsburg, 05361-9-0. Für 2002 + 2003: Dr. Michael Mrowietz (Umweltplanung Produktion/Standorte), 08.09.03 + 07.06.04.
Volvo Car Germany GmbH. Terminated in 2002, as all cars had AC-systems.

Winfried Schwarz/Jochen Harnisch: Establishing the Leakage Rates of Mobile Air Conditioners. Report on the EU Commission (DG Environment). Frankfurt/Nürnberg 2003. http://www.oekorecherche.de/english/berichte/volltext/leakage_rates.pdf.
AGRAMKOW Fluid Systems A/S, Sonderborg (Dänemark), +45 74123636. Bjarne Lund (Divisionsleiter), pers. comm. at VDA-Wintermeeting in Saalfelden 2003, 14.02.03.

Truck Air Conditioning (2.F.1)

Kraftfahrt-Bundesamt, Statistische Mitteilungen, Reihe 3: Kraftfahrzeuge, Neuzulassungen – Besitzumschreibungen - Löschungen von Kraftfahrzeugen und Kraftfahrzeuganhängern, Jahresband 2002 und 2003.
VDA (Verband der Automobilindustrie), Frankfurt, Analysen zur Automobilkonjunktur 2003, Jahrespressekonferenz am 29. Januar 2004 (Tabellenteil).
DaimlerChrysler AG (Werk Wörth), 07271-71-0. Für 2002: Frank Renz (VL/ASI) –4675, 01.10.03. Für 2003: Mattias Matejov (VL/ASI), 14.09.04 (Modelle Actros und Atego).
DaimlerChrysler AG, Stuttgart, 0711-17-0. Für 2002: Oliver Krenz (Produktmanagement MB-Van), 19.09.03. Für 2003: Christopher Khanna, 21.07.04 (Modelle Vito und Sprinter).
Volkswagen AG, Werk Hannover, 0511-798-0. Für 2002 + 2003: Stefan Schmitz (Zentrale Absatzplanung Nutzfahrzeuge), 01.09.03 + 15.06.04 (Modelle Transporter/Caravelle, LT, Caddy).
Deutsche Renault AG, Brühl, 02232-73-0. Für 2002 + 2003: Angela Lehmann (Produktkommunikation), 23.10.03 + 08.06.04 (Modelle Master und Kangoo).

Bus Air Conditioning (2.F.1)

Kraftfahrt-Bundesamt, Statistische Mitteilungen, Reihe 3: Kraftfahrzeuge, Neuzulassungen – Besitzumschreibungen - Löschungen von Kraftfahrzeugen und Kraftfahrzeuganhängern, Jahresband 2002 und 2003.
VDA (Verband der Automobilindustrie), Frankfurt, Analysen zur Automobilkonjunktur 2003, Jahrespressekonferenz am 29. Januar 2004 (Tabellenteil).
EvoBus GmbH, Ulm, 0731-181-0.
Für 2002: Sonja Waldenspul (Vertrieb), 24.09.03.
NEOPLAN Bus GmbH, Stuttgart, 0711-7835-0. Für 2002 + 2003: Dr. Jörg Kirsamer (Leiter Kompetenzcenter HLK NEOMAN), 23.09.03 + 17.09.04.

Air Conditioning of Agricultural Machines (2.F.1)

Kraftfahrt-Bundesamt, Statistische Mitteilungen, Reihe 3: Kraftfahrzeuge, Neuzulassungen – Besitzumschreibungen - Löschungen von Kraftfahrzeugen und Kraftfahrzeuganhängern, Jahresband 2002 und 2003.
CLAAS KGaA mbH, Harsewinkel, 05247-12-0.
Für 2002 (Combines and Crop choppers): Heinrich Sternberg (Technischer Kundendienst) infoclaas@claas.com, 23./24.09.03.
John Deere, Werke Mannheim, 0621-829-02.
Für 2002 + 2003 (Tractors, Combines, Crop choppers): Dr. Neumann (Pressesprecher), 24.09.03 + 17.09.04.
AGCO GmbH & Co. OHG, Marktoberdorf, 08342-77-0.
Für 2002 + 2003 (Tractors): Hr. Schmid (Kundendienst), 23.09.03 + 17.09.04.

SAME Deutz-Fahr Deutschland GmbH, Lauingen, 09072-997-0.
Für 2002 (Tractors and Combines): Hr. Graf (Konstruktion), 06.11.03. Für 2004: Hr. Leopold, 20.09.04.
VDMA, Fachverband Landtechnik, Frankfurt, 069-6603-1298. Gerd Wiesendorfer, 06.11.03.
Franz Hensen: http://home.t-online.de/home/hensen/#markt
VDMA, Fachverband Landtechnik, Frankfurt. Wirtschaftsbericht 2003.
http://www.vdma.org/vdma_root/www_lav_vdma_de/

Ship Air Conditioning (2.F.1)

Wasser- und Schifffahrts-Direktion (WSD) Südwest, Mainz, 06131-979-0.
Für 2002+2003: Andrea Hauf (Zentrale Binnenschiffsbestandsdatei), 18.11.03 + 15.09.04.
Statistisches Bundesamt, Wiesbaden, 0611-75-1: Für 2002:Hr. Kober, 07.10.03.
Verband Deutscher Reeder e.V. (VDR), Hamburg www.reederverband.de 040-35097-0.
Für 2002+2003: Bernd Titel (Statistik), 06.10.03 + 07.09.04.
Reederei Peter Deilmann, Neustadt in Holstein www.deilmann-kreuzfahrten.de 04561-396-0.
Für 2002+2003: Frau Polanski, 07.10.03.
http://www.deutschemarine.de/80256B100061BA9B/vwContentFrame/N256DM2T116MMISDE
http://www.blohmvoss.com/d/prod/frigate_f124.html
Noske-Kaeser GmbH, Hamburg, 040-8544-0.
Für 2002+2003: Volker Behrens, 23.09.03.
York Industriekälte GmbH & Co. KG, Marine, Hamburg, 040-670511-0.
Hr. Höft, 29.09.03.
Verband für Schiffbau und Meerestechnik e.V. (VSM) www.vsm.de Hamburg, 040-280152-0.
VSM-Jahresberichte 2002 + 2003. Downloadable from www.vsm.de.
Jos. L. Meyer GmbH www.meyerwerft.de, Papenburg, 04961-81-0.
Peter Hackmann (Leiter Öffentlichkeitsarbeit), 28.11.03.
Details on large passenger ships from this shipyard on their website.

Rail Vehicle Air Conditioning (2.F.1)

Deutsche Bahn AG, Hauptverwaltung Frankfurt, 069-265-0.
Für 2002: Klaus Reum (UB Personenverkehr – Zentrale Halteraufgaben, Betriebssicherheit Regio-Wagenzüge), 26.09.03. Für 2003: Geschäftsberichte DB Fernverkehr AG, DB Regio AG, Broschüre Daten & Fakten 2003.
Connex Verkehr GmbH, Berlin, Für 2002+2003: Hr. Schulze, 08.09.04.
Dr. Ulrich Adolph (Entwicklungsberater Kälte- und Klimatechnik) Leipzig, pers. Mitt. Bonn (DKV-Tagung), 21.11.03.
Konvekta AG, Schwalmstadt,06691-76-0. Michael Sonnekalb, pers. Mitt. bei der DKV-Tg. 2003 in Bonn, 21.11.03.

Rigid Foam (2.F.2)

Other PU Rigid Foam (2.F.2)

Thyssen Bausysteme GmbH, Werk Hof, 09281-7283-0.
Für 2002+2003: Peter Schaffiner, 22.9.03 + 14.09.04.
Solvay Fluor GmbH, Hannover, 0511-857-0.
Für 2002: Dr. Lothar Zipfel (Manager Foam Blowing Agents), 24.09.03. Für 2003: Dr. Ewald Preisegger, 03.09.04.

PU Integral Skin Foam (2.F.2)

Elastogran GmbH, Lemförde, 05443-12-0.
Für 2002+2003: Karl-Wilhelm-Kroesen (Ökologie und Produktsicherheit), 23.09.03 + 14.09.04.
Für 2002: Dr. Lothar Zipfel (Manager Foam Blowing Agents), 24.09.03. Für 2003: Dr. Ewald Preisegger, 03.09.04.

PU One Component Foam (2.F.2)

Für 2002+2003: Ad. K. van der Rhee, Autra Den Braven Aerosol GmbH + Co KG, Reichenberg-Albertshausen, und Peter Geboes (Soudal NV, Turnhout), Schreiben 22.09.03.
Polypag AG, Appenzell, Achim Niemeyer (Managing Director), 21.09.04.

XPS Insulating Foam (2.F.2)

FPX: Fachvereinigung Polystyrol-Extruderschaumstoff e.V. (German Section of EXIBA European Extruded Polystyrene Insulation Board Association) info@fpx-daemmstoffe.de , Frankfurt, 069-424901, Für 2002: Otmar Jochum, 23.09.03.
GEFINEX-JACKON GmbH, Mechau, 039036-960-0. Dr. Mark Plate, 19.02.03.
GDI: Gesamtverband Dämmstoffindustrie, GDI-Baumarktstatistik (Angaben in 1.000 m^3 , Frankfurt am Main, 01.04.2003.
Cefic European Chemical Industry Council, APME Association of Plastics Manufacturers in Europe. Carol Banner, 20.09.04.

Fire Extinguishers (2.F.3)

Kidde Deugra Brandschutzsysteme GmbH, Ratingen, 02102-405-0.
Für 2002+2003: Peter Clauss, 23.09.03 + 27.10.04.
Amtliche Prüfstelle für Feuerlöschmittel und – gerät bei der Materialprüfungsanstalt für das Bauwesen Dresden, Außenstelle Freiberg, 03731-34850, Für 2002 + 2003: Mitt. an das Umweltbundesamt, 02.07.03 + 21.01.04.

Aerosols/MDIs (2.F.4)

Metered Dose Inhalers (MDI) (2.F.4)

Arbeitskreis Pulverinhalation (API), Für 2002 + 2003: pers. Mitt. der darin vertretenen Pharmaunternehmen (GlaxoSmithKline, AstraZeneca u.a.) an ÖR, 16.09.03 + 20.04.04.
Boehringer-Ingelheim Pharma KG, Ingelheim, 06132-77-0.
Dr. Michael Köhler, Mitt. an ÖR, 30.09.03 + 01.10.04.

General Aerosols (zu 2.F.4)

Industriegemeinschaft Aerosole e.V. im VCI, Frankfurt am Main, Matthias Ibel, Schreiben an ÖR, 04.03.03, 01.07.03. Mitt. 10.06.05.
IG-Sprühtechnik, Wehr, Klaus Broecker, Mitt. an ÖR, 02.07.03 + 14.09.04.
Tunap Deutschland, Wolfratshausen, Lothar Stockert, Mitt. und Schreiben an ÖR 01.07.03.

Novelty Aerosols (2.F.4)

Industriegemeinschaft Aerosole e.V. im VCI, Frankfurt am Main, Matthias Ibel, Schreiben an ÖR, 04.03.03, 01.07.03. Mitt. 10.06.05.
WECO Pyrotechnische Fabrik GmbH, Eitorf/Sieg, 02243-833-0, www.weco-pyro.de, Erwin Lohmann, Mitt. an ÖR, 15.07.03.

Solvents (2.F.5)

Biesterfeld Chemiedistribution GmbH & Co. KG, Hamburg, 040-32208-0.
Für 2002+2003: K. Burmester (Marketing und Beschaffung), 04.12.03 + 29.04.04.
DuPont de Nemours International S.A., Geneva, Switzerland.
Alexandre Petit-Pierre (Manager Europe/MEA Fluorochemicals Specialties), Mitteilung an das Umweltbundesamt Berlin, 30.09.03.

Production of HFC-134a, HFC-227ea, SF_6 (2.E.2)
HFC-23 as By-Product (2.E.2)

Solvay Fluor und Derivate GmbH, Dr. Ewald Preisegger, Confidential communication to ÖR on "Production in Germany, associated emissions and export quantities of HFC and SF_6 of Solvay Fluor und Derivate GmbH (in t)", 16.10.03. Communication "Production in Germany and associated emissions of HFC and SF_6 (in t)", 28.10.04.

Equipment for Transmission and Distribution of Electricity (2.F.7)

Annual Reporting of Monitoring Data to Federal Ministry of Environment and to German Umweltbundesamt by the Section Switchgear, Control gear, Industrial Control Equipment in ZVEI (Electrical and Electronic Manufacturers' Association) – based on the 1997 Self-Commitment on SF_6 in Electrical Switchgear by the Association of German Electric Utilities (VDEW) and the Electrical and Electronic Manufacturers' Association (ZVEI), Frankfurt 2003 and 2004.

Soundproof Glazing (2.F.8)

Messer Griesheim GmbH (jetzt Air Liquide Deutschland GmbH), Krefeld, 02151-379-0.
Für 2002: Lutz Thiedecke (Vertriebskanäle/Marketing Deutschland), Mitt. an ÖR 22.09.03.
Für 2003: Lutz Thiedecke (Business Manager Helium, Fluorine and Rare Gases), Mitt. an ÖR, 26.08.04.
Air Products GmbH, Hattingen, 02324-689-0.
Für 2002: Kai Schwarz, Mitt. an ÖR, 22.09.03 + 08.09.04.
Linde AG, Höllriegelskreuth, 089-7446-0.
Für 2002: Dr. Hans-Jürgen Diehl (Zentraler Vertrieb Spezialgase), Mitt. an ÖR, 17.09.03 + 13.09.04.
Air Liquide GmbH, Düsseldorf, 0211-6699-0.
Für 2002: Stefan König, Mitt. an ÖR, 16.07.03.

Car Tires (2.F.8)

Messer Griesheim GmbH (jetzt Air Liquide Deutschland GmbH), Krefeld, 02151-379-0.
Für 2002: Lutz Thiedecke (Vertriebskanäle/Marketing Deutschland), Mitt. an ÖR 22.09.03.

Für 2003: Lutz Thiedecke (Business Manager Helium, Fluorine and Rare Gases), Mitt. an ÖR, 26.08.04.
Air Products GmbH, Hattingen, 02324-689-0.
Für 2002: Kai Schwarz, Mitt. an ÖR, 22.09.03 + 08.09.04.
Linde AG, Höllriegelskreuth, 089-7446-0.
Für 2002: Dr. Hans-Jürgen Diehl (Zentraler Vertrieb Spezialgase), Mitt. an ÖR, 17.09.03 + 13.09.04.

Tracer Gas (2.F.8)

FZ Jülich, Abteilung Sicherheit und Strahlenschutz, 02461-61-0.
Für 2002 + 2003: Hr. Möllmann, 24.09.03.

Magnesium Casting (2.C)

Schweizer & Weichand GmbH, Murrhardt, 07192-212-0.
Für 2002 + 2003: Klaus Horny, 10.09.03 + 20.09.04.
Honsel-Alumetall GmbH, Nürnberg, 0911-4150-0.
Für 2002 + 2003: Hr. Dötsch (Einkauf), 08.09.03 + 13.09.04.
Dietz-Metall GmbH & Co. KG, Unterensingen, 07022-6098-0.
Für 2002 + 2003: Rudolf Schmidt (Instandhaltung), 10.09.03 + 22.09.04
AMZ-Weißensee Präzisionsguss, Berlin, 030-92092138.
Für 2002: Hr. Dokter, 10.09.03. Für 2003: Hr. Rossbacher, 01.09.04.
Metallgießerei Wilhelm Funke, Alfeld (Leine), 05181-8459-0.
Für 2002 + 2003: Hr. Dreier (GF), 10.09.03 + 01.09.04.
Metallwerke Kloß Maulbronn GmbH, Maulbronn, 07043-13-0.
Für 2002 + 2003: Winfried Reiling (UWS), 09.09.03 + 23.09.04.
Kolbenschmidt-Pierburg AG, Nettetal, 02153-124-1.
Für 2002 + 2003: Wilhelm Extra (Leiter Vorfertigung), 09.09.03 + 14.09.04.
Takata-Petri AG, Aschaffenburg, 06021-65-0.
Für 2002: Ullrich Geis (Mg.Gießerei), 16.09.03. Für 2003: Hakan Ueccesmeler (Safety & Environment), 06.09.04.
Volkswagen AG, Werk Kassel, Baunatal, 0561-490-0.
Für 2002 + 2003: Helmar Pflock (UWS), 16.09.03 + 20.09.04.
TRW Automotive GmbH, Aschaffenburg, 06021-314-0.
Für 2002 + 2003: Reinhold Köhler (AS/UWS), 09.09.03 13.09.04.
Dynacast Deutschland GmbH, Bräunlingen, 0771-9208-0.
Für 2002 + 2003: Sigmund Holzer (Einkauf), 11.09.03 + 01.09.04.
Druckguss Heidenau GmbH, Dohna, 03529-588-0.
Für 2002 + 2003: Niehoff (Einkauf), 09.09.03 + 01.09.04.
HDO-Druckguss- und Oberflächentechnik GmbH, Paderborn, 05251-704-0.
Für 2002 + 2003: Ferdinand Brakhane (Sicherheit/Umwelt),12.09.03 + 14.09.04.

Aircraft Radar (2.F.8)

NATO Fliegerhorst AWACS, Geilenkirchen, 02451-63-0.
Für 2003: Hr. Drieling (Radar Shop), 24.09.03; 08.01.04.
EADS (European Aeronautic Defence and Space) Deutschland GmbH, Manching, 08459-81-01. Für 2003: Dietmar Berszik, 23.09.03.
Linde AG, Höllriegelskreuth, 089-7446-0.
Für 2002: Dr. Hans-Jürgen Diehl (Zentraler Vertrieb Spezialgase), Mitt. an ÖR, 17.09.03 + 13.09.04.

Sport Shoe Soles (2.F.8)

SF_6 in sport shoes, Ch. 4.3, in: Costs and the impact on emissions of potential regulatory framework for reducing emissions of hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride (final report). Prepared on behalf of the European Commission (DG ENV), by J. Harnisch (Ecofys) & W. Schwarz (Öko-Recherche), February 4, 2003, p. 22-23. http://www.oekorecherche.de/english/berichte/volltext/ecofys_oekorecherchestudy.pdf.

BMU, Confidential communication on use of SF_6 and PFC-218 in sport shoe soles, 29.09.2004.

Particle Accelerators (2.F.8)

Öko-Recherche, Total Survey on Particle Accelerators in Germany, in: Winfried Schwarz: Emissions, Activity Data, and Emission Factors of Fluorinated Greenhouse Gases (F-Gases) in Germany 1995-2002. Adaptation to the Requirements of International Reporting und Implementation of Data into the Centralised System of Emissions (ZSE), June 2005, UBA-Text 15/05, p. 252-258 (http://www.umweltbundesamt.org/fpdf-l/2903.pdf)

Optical Glass Fibres (2.F.8)

Messer Griesheim GmbH (jetzt Air Liquide Deutschland GmbH), Krefeld, 02151-379-0.
Für 2002: Lutz Thiedecke (Vertriebskanäle/Marketing Deutschland), Mitt. an ÖR 22.09.03.
Für 2003: Lutz Thiedecke (Business Manager Helium, Fluorine and Rare Gases), Mitt. an ÖR, 26.08.04.

Air Products GmbH, Hattingen, 02324-689-0.
Für 2002: Kai Schwarz, Mitt. an ÖR, 22.09.03 + 08.09.04.

Linde AG, Höllriegelskreuth, 089-7446-0.
Für 2002: Dr. Hans-Jürgen Diehl (Zentraler Vertrieb Spezialgase), Mitt. an ÖR, 17.09.03 + 13.09.04.

Air Liquide GmbH, Düsseldorf, 0211-6699-0.
Für 2002: Hr. König, Mitt. an ÖR, 16.07.03.

Power Capacitors (2.F.8)

Communication by ZVEI, Section Switchgear, Control gear, Industrial Control Equipment, to ÖR, Frankfurt am Main, 25.05.04.

Aluminium Cleaning (2.C)

Linde AG, Höllriegelskreuth, 089-7446-0.
Für 2002: Dr. Hans-Jürgen Diehl (Zentraler Vertrieb Spezialgase), Mitt. an ÖR, 17.09.03 + 13.09.04.

Westfalen AG, Münster, 0251-695-0.
Für 2003: Hr. Kohnert (Sondergase), 22.09.03.

Aluminium Rheinfelden GmbH, Rheinfelden (Baden) 07623 93-0.
Für 2003: Hr. W. Glück (Umweltbeauftragter), 14.10.03.

Manufacture of Printed Circuit Boards (2.F.6)

plasonic Oberflächen GmbH, Gerlingen, 07156-9439-0.
Hr. Marek (Geschäftsführer), 25.09.03.

Linde AG, Werksgruppe Technische Gase, Unterschleißheim, 089-31001-0.
Ralf Hollenbach (Anwendungstechnik Elektronikgase), 22.09.03.

Semiconductor Manufacturing (2.F.6)

ZVEI (Components Division): Voluntary Reporting of PFC-Emissions of the German Semiconductor Industry for 1995 – 2002, and for 1995 – 2003, to the Federal Ministry of Environment and the German Umweltbundesamt, 22.05.2003 + 28.05.04.

Production of Aluminium (2.C)

Primary Aluminium Chapter in the Federation of German Aluminium Industries: Monitoring Reports on Progress in Reduction of CF_4/C_2F_6 Emissions from the German Primary Aluminium Industry for the years 2002 and 2003, Berlin, 18.08.03 + 07.09.04.

Second Chapter. Forecasting 2010 and 2020 Emissions

In the following, emission forecasts for 2010 and 2020 are elaborated pursuant to four different scenarios. Section I describes the scenarios themselves and gives short comments on the respective 2010 and 2020 emissions. After, section II presents in three sub-sections (1.-3.) for each of the three substance groups HFCs, PFCs, and SF_6, both detailed 2010 and 2020 emission data pursuant to the four scenarios in Tables 10 – 15 (in metric tonnes as well in tonnes CO_2 equivalent) and explains the underlying scenario assumptions sector by sector.

For more clearness, Tables 10 - 15 show emissions in the three substance groups subdivided into rather large sectors and sources. Therefore, in section III an annex follows with spreadsheet data that are more detailed. It should be mentioned that some data are confidential, so that complete reproduction of each individual emission is not possible there.

I. Four Emission Forecasting Scenarios

Table 9 lists the 2010 and 2020 emission forecasts according to their four underlying scenarios. The overall global warming emissions are disaggregated into three substance groups.

Table 9: HFC, PFC, and SF_6 Emission Forecasts (million t CO_2 equivalent)

	Initial Values (Baseline)	I. Without Measures from 1999		II. With measures through 2003		III. EU Legislation 2007		IV. With further Measures	
	1995	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**
HFC	6.479	18.513	20.480	13.908	15.437	10.992	9.626	9.419	5.869
PFC	1.750	1.720	2.786	0.652	0.631	0.634	0.610	0.551	0.519
SF_6	7.235	7.875	10.556	5.438	7.514	4.418	6.045	3.169	4.579
Total	**15.464**	**28.108**	**33.822**	**19.998**	**23.582**	**16.045**	**16.281**	**13.139**	**10.967**

Sources: Sector specific data in section II of this chapter.

Scenario I "Without Measures from 1999"

The first scenario is a "without measures projection" because it assumes the trends emerging in the 1995-1998 period to continue, and extrapolates these to the years 2010 and 2020. That is why "Without Measures" actually means "Without new measures after 1998". The scenario includes measures that got started or going between 1995 and 1998. Nevertheless, it is essentially a business-as-usual scenario.

In case of closed equipment historic emission rates are kept unchanged, future improvement of equipment tightness is not accounted for. However, in the individual sectors it is tried to anticipate increases or decreases in the used gas quantities that were likely to happen from the point of view at that time. This scenario is so to speak the "worst case" from a year 1998 perspective and thus the baseline or reference projection for the following three scenarios. The lower their projected emissions go below that "Without Measures" level, the higher is the progress in climate protection that is expressed by them.

In this scenario, F-gas global warming emissions rise to 28.1 million t CO_2 equivalent, and further to 33.8 million t by 2020 (cf. Table 9). This is a doubling of the 1995 baseline figures (15.46-million t CO_2 equivalent). Then, two thirds of all emissions are HFCs, having substituted historic CFCs and HCFCs for the most part.

According to Table 11 (in next section), in 2020 the largest HFC emitters in terms of global warming are as follows (in brackets the forecasted sector-emissions in million tonnes CO_2 equivalent).

1. Stationary Refrigeration and AC (6.1).
2. Mobile Air Conditioning (5.6).
3. Foaming (XPS, OCF, PU foam products) (4.5).
4. Production of Halocarbons (2.8).
5. Aerosols (MDIs, other Aerosols) (1.3).

Table 13 (in next section) lists the PFC emissions that would have presumably arisen by 2010 and 2020 respectively, if the 1995-1998 usage trends had continued. Here, only the 2020 emissions are shown for the largest sectors:

6. Semiconductor Manufacture (1.8; plus etching gases SF_6 and HFC-23: 2.3).
7. Aluminium Production (0.95).

Finally, from Table 15 (next section) the SF_6 sectors with the highest global warming emissions by 2020 can be read off:

8. Soundproof Glazing (4.7).
9. Magnesium Casting (1.7).
10. Equipment for Electricity Transmission and Distribution (1.1)
11. Aluminium Cleaning (0.95).
12. Car Tires (0.7).

In the first scenario, the above 12 sectors account for more than 96% of all global warming F-gas emissions that would have arisen by 2020, if the 1995-1998 usage trends in Germany had continued to run unabatedly and had not been stopped or even turned back here and there.

Scenario I "Without Measures from 1999" is comparable to the Business-as-Usual scenario in the 1999 study for the Umweltbundesamt (Schwarz/Leisewitz 1999). This six year old 2010 B-a-U scenario (a 2020 scenario was not elaborated then) projected 27.4 million t CO_2 emissions, which are not far away from the now forecasted 2010 emissions of 28.1 million t CO_2 equivalent. The coincidence in the total figure, however, hides strong differences in their sub segments. In 1999, HFCs were projected higher by 1.5 million t CO_2 equivalent and PFCs by 0.7. On the other hand, SF_6 was forecasted lower by 2.8 million t. The discrepancies are caused firstly by the fact that the old B-a-U scenario only extrapolates 1995-1997 trends, while now the year 1998 is included in the baseline emissions, too; secondly by comprehensive recalculation of the real emissions and consumption quantities before 1998, which was carried out in the frame of the aforementioned study for the Umweltbundesamt in 2003 and 2004. Above all, in some application sectors of SF_6, so far understated gas quantities had to be corrected upwards retroactively. This applies to aluminium and *magnesium industry, manufacture of electrical components, aircraft radar, and soundproof glazing. In contrast to this, PFC emissions were estimated lower, which is an outcome of semiconductor emissions abatement setting in as of 1998. As to HFCs, the HFC-23 by-product emissions had to be rated higher for the 1995-1998 as an outcome of new findings provided by the manufacturer.*

Scenario II "With Measures through 2003"

The second scenario "With measures through 2003" ("with measures projection") is based on measures that had already been implemented prior to the year 2004. Until 2010 and 2020, respectively, it disregards any policy or measure that was or will be carried out after 2003; it includes, however, efforts to emission reduction made from 1999 onwards. Essentially, it differs from scenario I insofar as it extrapolates the present, i.e. 2003, usage and emission trends to the future. These ran in a fair number of cases (e.g. in PU and XPS manufacturing) clearly below the level relevant for scenario I.

As a matter of fact, over the five years after the 1995-1998 period, i.e. from 1999 to 2003, there were several measures taken which are likely to cause a far slower growth in total global warming F-gas emissions, than forecasted in scenario I. Certainly, main reason for reduction measures was the inclusion of the three F-gas groups in the Kyoto Protocol in December 1997, what increased public attention. Discussions arose everywhere about risks and benefits of F-gases and about alternatives to them, especially when used in highly emissive applications such as car tires, soundproof glazing, magnesium casting, foam blowing, aerosols, semiconductor industry, and manufacturing of some electrical equipment. These sectors were joined by those that emit F-gases as unintentional by-products, namely aluminium production (CF_4, C_2F_6) and production of HCFC-22 (HFC-23).

Emission forecast based on the second scenario shows that in recent years considerable environmental efforts have been made. In comparison to no further measures after 1998 (scenario I), 2010 emissions are likely to be lower by some 8 million t CO_2 equivalent, 2020 emissions even by 10 million t (23.6 compared to 33.8 million t) which corresponds to a reduction of 30% against that "worst case".

The most important emission reductions by 2020 compared to the respective figures in scenario I are expected to take place in the sectors listed below (in brackets and in negative numbers the calculated emission reduction relative to the first scenario, in million tonnes CO_2 equivalent, according to Tables 11, 13, and 15):

1. HFC-23 by-product emissions (- 2.3).
2. Semiconductor industry with all applied F-gases (- 2.1).
3. Foams (OCF, XPS, PU rigid foam) blown with HFCs (- 1.9).
4. Soundproof glazing (- 0.9).
5. Car tires (- 0.65).
6. Aluminium production (- 0.55).
7. Electrical equipment for T&D (- 0.42).
8. Industrial refrigeration (- 0.4).
9. Magnesium casting (- 0.4).
10. Metered Dose Inhalers (- 0.35).

As shown above, all substance groups are involved in this substantially attenuated rise in emissions. The ten sectors account for reduction in global warming emissions of 10 million t CO_2 equivalent. Nonetheless, the 1995 baseline emissions will be markedly surpassed due to strong growth in HFC emissions. Driving forces of the latter growth are predominantly the sectors of stationary refrigeration and mobile air conditioning. In refrigeration, almost one-to-one substitution of previous CFCs and HCFCs is taking place, and in mobile air conditioning, even extension of refrigerant use far in excess of the former CFC level has to be stated.

Scenario III "EU legislation 2007"

The third scenario "EU legislation 2007" is based on the implementation of both the "EC Regulation on certain fluorinated greenhouse gases" and the "EC Directive relating to emissions from air conditioning systems in motor vehicles", both of which are in the final state of their political adoption (Oct 2005). The projection ("with measures projection") serves to assess the effects on emissions that follow from this political measure, which undoubtedly is of the highest importance for fluorinated greenhouse gases in this decade.

Table 9 shows that the EU policy can cause 2010 emissions to drop by further approx. 4 million t CO_2 equivalent compared with the measures already implemented by 2003, which are underlying the second scenario. By 2020, the reduction effect as a result of EU legislation will amount to even more than 7 million t CO_2 equivalent or 30%, with16.3 million t CO_2 equivalent instead of 23.6 million t.

The EU legislation hardly causes reduction in PFC emissions, and the effect on SF_6 emissions is not very large either. The only, but very important exemption is magnesium casting where the ban on SF_6 as a cover gas in large foundries will cut their emissions by 1 million t CO_2 equivalent. It is HFC emissions that will drop most by 2020; savings of almost 6 million t CO_2 global warming emissions can be achieved compared to the scenario "With measures through 2003", namely 9.6 instead of 15.4 million t CO_2 equiv., which is a reduction of 37%. The weightiest sectors in terms of their 2020 reduction potential are, in the following order (in brackets potential savings in million t CO_2 equivalent according to Tables 11, 13, and 15 in the next section):

1. Mobile air conditioning where chiefly CO_2 replaces HFC-134a refrigerants (- 2.8).
2. Stationary Refrigeration and AC, where mandatory maintenance and leakage control can substantially lower use-phase emissions (- 2.0).
3. One-Component-Foam in cans, with natural propellants substituting HFCs (- 0.6).

Scenario IV "With further Measures"

The fourth scenario is called "With further measures". This is because it presents a new reduction scenario with additional measures that go beyond the currently intended EU F-gas legislation, but are considered realisable over the medium and long term.

Table 9 shows for the year 2020 again possible savings of more than 5 million t CO_2 equivalent emissions as an outcome of further reduction measures. The sectors that offer the largest emission reduction potential compared to the third scenario of the forthcoming EU legislation are in the following order (in brackets potential emission savings in million t CO_2 equivalent, according to Tables 11, 13, and 15 in the next section):

1. XPS foam blown by natural fluids only instead of HFCs (- 1.0).
2. Secondary aluminium smelters where SF_6 is completely dispensed with (- 1.0).
3. Stationary refrigeration and AC where natural fluids play a major part thus limiting use of HFCs (- 0.9).
4. Rigid PU foam with HFC-free blowing agents being used exclusively (- 0.6).
5. Metered Dose Inhalers the use of which is reduced by more DPIs (- 0.3).
6. Technical aerosols no longer using HFC propellants (- 0.2).

Instead of 33.8 million t CO_2 equivalent emissions in the first scenario, 23.6 million t in the second, and 16.3 million t in the third, in the final scenario 2020 global warming emissions amount to only 11.0 million t CO_2 equivalent.

While by 2020 as an outcome of the EU legislation the 1995 baseline emissions are still exceeded, further measures pursuant to scenario IV can cut the 2020 total global warming emissions markedly, namely by almost 30% below that initial level.

II. Forecasts by Substance Groups, and Sector Assumptions

Subsequently, the assumptions that form the basis of all the four scenarios are described sector-by-sector, and the projected emissions of HFCs, PFCs, and SF_6 are presented in detail, each in two tables (in metric tonnes and in million t CO_2 equivalent).

1. 2010 and 2020 HFC Emissions

1.1 Stationary Refrigeration and Air Conditioning

Introductory note. In both stationary and mobile refrigeration and air conditioning, there is no difference between the first two scenarios "Without measures from 1999" and "With measures through 2003" – apart from industrial refrigeration. Reason for this identity is that over the 1995-2003 periods virtually no measures were taken that interfered with a one-to-one conversion from chlorine-containing refrigerants to HFCs. The old banks of CFCs/HCFCs were (and are) continuously replaced, in refrigeration at the same level, in air conditioning at a substantially higher level. Yet, natural refrigerants play under part despite of spectacular individual application cases. The important substitution of CFCs in domestic refrigerators by hydrocarbons in place of HFCs had been carried out prior to 1995. Hence, it does not affect the "Without measures from 1999"-scenario, which embodies the developments of the 1995-1998 period, and extrapolates them to the future.

In the following, sector-by-sector the assumptions are outlined that form the basis of the 2010/2020 emission forecasts. As emissions estimation is very complex in case of refrigeration and air conditioning, for further information the reader is referred to the study "Emissions, Activity Data, and Emission Factors of Fluorinated Greenhouse Gases (F-Gases) in Germany 1995-2002" (UBA-Text 15/05).

1.1.1 Industrial Refrigeration

In industrial refrigeration both in scenario "Without measures from 1999" and "With measures through 2003", an operating emission rate of 7% is applied to the average annual refrigerant bank, and at end-of-life a loss-factor of 30% is used. Filling emissions amount to 0.15% of new domestic consumption. These figures relate to a full refrigerant bank, which is supposed to be stable over the medium term. In its (not yet reached) final state, this bank is assumed to run qualitatively only with HFCs, and quantitatively at the same level as with CFC/HCFC refrigerants.

It should be noted, this special determination of the future refrigerant bank does not only apply to industrial refrigeration but also to commercial refrigeration (1.1.2).

In the first scenario, emissions are higher than in the second because it assumes a 25% higher share of HFCs in overall refrigerants compared to ammonia and CO_2.

Compared with that, the second scenario includes the trend to a higher level of R-22 substitution by ammonia, which has emerged since 1999.

Table 10: HFC Emissions 1995, 2010, and 2020 (t)

Sectors	1995 baseline	Without measures from 1999		With measures through 2003		EU Legislation 2007		With further Measures	
	1995	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**
Stationary Refrig./AC	73	2255	2496	2128	2368	1511	1567	1501	1194
Mobile Refrig./AC	170	3810	4219	3810	4219	3498	2376	3475	1785
- thereof passenger cars	*133*	*3306*	*3577*	*3306*	*3577*	*3013*	*1777*	*2990*	*1391*
PU One-Component Foam	1823	1844	1844	1048	1048	52	52	0	0
Other PU Foam	0	749	1072	446	598	446	598	186	65
XPS Insulating Foam	0	3666	4503	2283	2810	991	829	480	23
Metered Dose Inhalers	0	443	595	286	384	286	384	235	179
Other Aerosols	254	275	275	275	275	172	172	2	2
Fire Extinguishers/Other	1.1	10.3	21.0	7.9	12.7	18.6	29.8	19.7	37.5
Subtotal (Use incl. of Mg)	**2319**	**13051**	**15024**	**10283**	**11715**	**6974**	**6008**	**5899**	**3258**
Other (Production)	360	272	272	74	74	74	68	52	46
Total	**2679**	**13323**	**15296**	**10357**	**11789**	**7048**	**6076**	**5950**	**3303**

Table 11: HFC-Emissions 1995, 2010, and 2020 (million t CO_2 equivalent)

Sectors	1995 baseline	Without measures from 1999		With measures through 2003		EU Legislation 2007		With further Measures	
	1995	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**
Stationary Refrig./AC	0.169	5.684	6.062	5.288	5.666	3.704	3.683	3.681	2.748
Mobile Refrig./AC	0.234	5.065	5.595	5.065	5.595	4.642	2.779	4.638	2.416
- thereof passenger cars	*0.172*	*4.297*	*4.650*	*4.297*	*4.850*	*3.890*	*1.862*	*3.887*	*1.808*
PU One-Component Foam	1.534	1.553	1.553	0.688	0.688	0.034	0.034	0	0
Other PU Foam	0	0.797	1.133	0.477	0.634	0.477	0.634	0.181	0.064
XPS Insulating Foam	0	1.438	1.798	1.028	1.287	0.900	1.077	0.236	0.030
Metered Dose Inhalers	0	0.717	0.963	0.451	0.607	0.451	0.607	0.370	0.283
Other Aerosols	0.318	0.339	0.339	0.339	0.339	0.212	0.212	0.003	0.003
Fire Extinguishers/Other	0.012	0.069	0.164	0.037	0.065	0.051	0.087	0.049	0.069
Subtotal (Use incl. of Mg)	**2.267**	**15.662**	**17.629**	**13.374**	**14.903**	**10.458**	**9.100**	**9.143**	**5.602**
Other (Production)	4.212	2.851	2.851	0.535	0.535	0.535	0.527	0.276	0.268
Total	**6.479**	**18.513**	**20.480**	**13.908**	**15.437**	**10.992**	**9.626**	**9.419**	**5.869**

In the third scenario "EU legislation 2007", in contrast to the first two scenarios, the intended mandatory equipment maintenance (as of 2007) is assumed to take effect. As a result, operating emission rate is assumed to sink from 7 to 6 percent by 2011. End-of-life loss will figure only 20% instead of 30%, from 2007 onwards. Filling emissions remain at 0.15% of annual domestic consumption[7].

The fourth scenario "With further measures" is based on the third scenario. Additionally, in this scenario new equipment that today would use HFCs is filled with natural refrigerants, beginning in 2010 with 25% of annual new consumption, and increasing to 50% by 2020. All emission factors (operation, disposal, and manufacturing) remain the same as in the third scenario.

1.1.2 Commercial Refrigeration

In the first two scenarios "Without measures from 1999" and "With measures through 2003" the assumptions are similar to those in industrial refrigeration. This means no quantitative growth in refrigerant bank and, for the time being, constant bank emission rates (on-site mounted systems 10%, old systems 15%, condensing units 5%, and hermetic equipment 1.5%) as well as 30% disposal emission rate. As in industrial refrigeration, emission rate on filling amounts to 0.15% of new domestic refrigerant consumption.

In contrast to the two above scenarios, in scenario "EU legislation 2007" (mandatory maintenance for equipment over 3 kg charge) operating emission rate drops within five years from 10% to 5% by 2011 for on-site mounted systems, and from 5% to 3.5% for condensing units. Operating EF of hermetic equipment remains equal. Refrigerant loss on disposal figures only 20% from 2007 onwards. Filling emissions are again considered 0.15% of new domestic consumption.

In scenario "With further measures" most assumptions are the same as in the "EU legislation"-scenario. The difference is that now natural refrigerants play a major part. New equipment that today would be filled with HFCs will be charged with natural refrigerants, beginning in 2010 with 10% of annual refrigerant consumption, gradually increasing to 50% until 2020.

1.1.3 Stationary Air Conditioning and Heat Pumps

Stationary air conditioning means both centralized systems for high performance the bulk of which is indirectly cooling chillers, and decentralized systems for lower performance where the refrigerant always evaporates directly. The first category includes on-site mounted centrifugal chillers, screw compressor systems, and systems with scroll and piston compressors. The second category is industrially manufactured room air conditioners in compact, split, and multi-split design. Unlike industrial and commercial refrigeration, stationary air conditioning is expected to experience strong growth in equipment installation and in the refrigerant bank. Thus, all scenarios share the common assumption of doubling the number of chillers and of

[7] It should be noted here that filling emissions, the estimation and monitoring of which is required for international reporting, affect total emissions just slightly. Emissions estimation could be well done without them without falsifying the overall results.

40% growth in new-installed room air conditioners by 2010. For heat pumps even tripling of the today's number is assumed by 2010. Because of their small specific charge of refrigerant, the role of heat pumps is secondary as to HFC bank (one tenth of the stock in room air conditioners, one twentieth of the stock in stationary chillers).

In the scenarios "Without measures from 1999" and "With measures through 2003" operating EF figures 6% in case of centralized systems and 2.5% in case of room air conditioners. EF of 2.5% is also applied to heat pumps in operation. Emissions on disposal are considered 30%. Relative filling emissions depend on equipment size and figure between 0.015% and 0.15% of new domestic consumption.

In the third scenario "EU legislation 2007", mandatory maintenance applies to equipment > 3 kg from 2007 onwards. Result is for larger air conditioning systems a drop in operating EF from 6% to 5% by 2011. The EF of room air conditioners and heat pumps is assumed to remain on the low level of 2.5%. Thanks to more careful handling, emissions on disposal generally sink to 20% from 2007 onwards.

As in industrial and commercial refrigeration, in the fourth scenario "With further measures" natural refrigerants play a substantial role in new equipment, from 2010 onwards. The share of HFC-free new systems rises until 2020 from 25% to 50%.

1.2 Mobile Air Conditioning and Refrigeration

1.2.1 Passenger Car Air Conditioning

Air conditioners in passenger cars account for more than 80% of HFC emissions from mobile systems. This is why the EC Directive on HFC-134a phase-out in passenger car air conditioners plays a key role for emission forecasting. The assumptions that form the common basis of all the scenarios are as follows: growth in air conditioning continues until the entire vehicle fleet has reached 95% penetration, what may be the case in 2017. Though charges of air conditioning units go on dropping slightly, the refrigerant bank in the cars continues to rise greatly over the next ten years.

In the scenarios "Without measures from 1999" and "With measures through 2003" disposal emissions (occurring from 2003 onwards) figure 30%. Average charge of new AC units drops as in the past by 1% annually. Filling emissions are 2 grams per unit; operating emission rate of the HFC-bank is 10%. This emission rate remains equal in the two following scenarios, too.

The scenario "EU legislation from 2007" supposes for new systems gradual phase-out of HFC-134a from 2008 onwards, lasting until end of 2016. This process takes so long because the introduction of new refrigerants is connected with changing the complete vehicle platform, not only the model. By law, 2011 is the first year for new passenger car platforms to do it without HFC-134a air conditioners. However, it is to be expected that some carmakers, as announced, start conversion earlier in favour of a more fluent transition. The refrigerant for new systems is supposed to consist of 80% CO_2 and 20% HFC-152a. The loss on disposal is no longer 30% but only 20%.

The scenario "With further measures" differs from the preceding scenario only insofar as new systems exclusively use CO_2 as alternative to HFC-134a, with HFC-152a not being applied at all.

1.2.2 Other Mobile Air Conditioning

The conversion to CO_2 in air conditioners of other land-based vehicles such as trucks, buses, agricultural machines, railcars, is in principle closely linked with the introduction in passenger cars. The forthcoming EC Directive does not yet provide for legally binding HFC-134a phase-out. This is why the three scenarios "Without measures from 1999", "With measures through 2003", and "EU legislation 2007" do not significantly differ from each other. In the third scenario, only a different emission factor on disposal is assumed with 20% compared to 30% in the first two scenarios. In the first three scenarios the operating emission rate of the refrigerant bank is 15% for middle and heavy trucks, for buses, railcars, and agricultural tractors, while for combines and crop choppers a higher emission rate of 25% is used. Light trucks are treated like passenger cars and have their, lower, emission rate of 10%.

Filling emissions are 5 grams per unit in buses and agricultural machines, and 2 grams per unit in trucks of all weight classes. For railcars a filling loss of 0.2% of the refrigerant charge is applied.

For each of the four above vehicle categories a fourth scenario "With further measures" is elaborated. It assumes from 2013 onwards in all new air conditioning systems exclusively natural refrigerants to be used in place of HFC-134a, such as CO_2, air, or even hydrocarbons. The conversion is completed in 2017. Legal opportunity to achieve that is offered by the forthcoming EC Directive itself, which provides for a review in the near future whether the HFC-134a phase-out should be extended to vehicles other than passenger cars. The delay in introduction compared to passenger car air conditioners results from the fact that for the time being only passenger cars are subject to the impending ban on HFC-134a.

For ships no differentiation is made in the four scenarios because the refrigerant quantities in question are too small. Operating emission rate and filling emission rate are set constant through all the scenarios, with 5% and 1%, respectively.

1.2.3 Refrigerated Vehicles

The following assumption forms the basis of all the four scenarios: For refrigerated vehicles continuous growth in refrigerant bank is expected. The growth, however, is 1.25 % per year and with that no longer as dynamic as in the time before 2003.

"Without measures from 1999" and "With measures through 2003": Operating emission rate of refrigerants banked in refrigeration equipment figures 15%, the one-off end-of-life loss is 30%. Filling loss is 5 grams per domestically filled piece of equipment.

Scenario "EU legislation 2007": No important alterations on the previous scenarios. Solely disposal emissions sink from 30% to 20%, from 2007 onwards.

Scenario "With further measures" assumes in addition that transport refrigeration is subject to mandatory maintenance, which the forthcoming EU legislation provides an opportunity for (review). Its implementation is assumed to take place gradually from 2013 to 2017. Hence, operating emissions drop from 15% to 10% over the same period. Disposal emissions remain at 20%.

1.2.4 Refrigerated Containers

Following assumption applies to all scenarios: ten percent of worldwide emissions are attributed to Germany according to its share in worldwide trade.

"Without measures from 1999" and "With measures through 2003": Operating emission rate figures 10% and one-off end-of-life loss 30%.

Scenario "EU legislation 2007": No relevant alterations on the previous scenarios. Solely disposal emissions sink from 30% to 20%, from 2007 onwards.

Scenario "With further measures" assumes mandatory maintenance as of 2013 as it does in case of refrigerated vehicles. Consequently, use-phase emission rate drops by 5% until 2017, from 10% to 5%.

1.3 Other HFC Applications

1.3.1 Metered Dose Inhalers MDI

Following assumptions form the basis of all scenarios: annual growth in market permanently amounts to 3%. Emissions depend on the respective share of dry powder inhalers compared to aerosol systems.

In scenario "Without measures from 1999" the 1998 market split remains constant, i.e. 75% MDI (CFC/HFC) and 25% dry powder inhalers (DPI).

Unlike the first scenario, scenario "With measures through 2003" extrapolates the 2003 DPI market share of 45% so that for MDIs only 55% of the market is left.

"EU legislation 2007" does not address medical aerosols. Hence, there is no difference from the second scenario.

Scenario "With further measures" expects the DPI market share to grow to 55% by 2010 and to 75% by 2020.

1.3.2 General Aerosols and Solvents

"General Aerosols" are (i) technical spray products such as compressed-air sprays and freezer sprays, (ii) household sprays such as drainpipe cleaners, and (iii) novelty sprays such as silly string for parties and that like. To a rather small extent some technical aerosols contain as a solvent HFC-43-10mee that is otherwise used – likewise in limited quantity (due to specific German solvent cleaning legislation) – in industrial precision cleaning of sensitive surfaces. Because of the small market relevance and for confidentiality, HFC-solvents are covered by "General Aerosols".

Both in scenario "Without measures from 1999" and in scenario "With measures through 2003" those quantities are assumed constant in the near future which have proved comparably stable between 1995 and 2003. In this period of time every year some 160 t HFCs (chiefly 134a) were used in technical and household sprays (inclusive of small amounts of solvent), and additionally 100 t in novelty sprays.

In scenario "EU legislation 2007", HFCs are no longer used for novelties from 2009 onwards (two years after the Regulation has entered into force).

Pursuant to "With further measures", from 2010 at the latest HFCs are no longer used in general aerosols either, apart from a tiny remainder.

1.3.3 Fire Extinguishers

In addition to HFC-227ea, in the first two scenarios "Without measures from 1999" and "With measures through 2003", HFC-23 and HFC-236fa are used, with operating emission rates of 1%, 2%, and 5%, respectively. Annual growth in bank amounts to 8% until 2018, then having ultimately replaced the now existing Halons. The substitution takes place through annual HFC-227ea consumption of 50 t, and, at a lower but increasing level, by HFC-23 with 5 t/y in 2010, and 10 t/y in 2020. The fire-extinguishing agent HFC-236fa is limited to military use, which is not assumed to expand. Disposal emissions figure 2% in case of HFC-227ea and 5% for HFC-23 and HFC-236fa. Filling emissions figure 0.1% of annual consumption.

"EU legislation 2007": No alterations vs. scenarios I and II.

The fourth scenario "With further measures" differs from the three preceding scenarios only in one point. The currently permitted, but not yet used, fire extinguisher HFC-23 is assumed never to be applied in Germany.

1.3.4 Semiconductors

The only HFC being used in semiconductor industry as an etching gas is HFC-23 (CHF_3). In the first scenario "Without measures from 1999", annual emissions growth rate of 10% is applied to the average 1995-1998 emissions, until 2010 and 2020, respectively. 10% was the real annual growth over that baseline period.

All the three scenarios "With measures through 2003", "EU legislation 2007", and "With further measures" assume a drop in emissions 10% below the 1995 baseline year emissions by the year 2010. This corresponds to the 1999 global emission reduction agreement signed by the World Semiconductor Council, which the German semiconductor industry has joined. Independently, since 1999 German manufacturers have initiated and implemented emission abatement and process optimization measures. From 2010 to 2020, emissions are assumed constant.

1.4 Foam

1.4.1 XPS-Foam

All scenarios assume annual 2% growth in domestic manufacture and consumption of XPS until 2010 and further until 2020. When using HFC-152a as blowing agent, its complete emission in the manufacturing year is supposed (First Year ER: 100%). No HFCs remain in the insulating foam so that there is no bank from which HFCs could emit during use-phase of the foam (operating ER = 0%). When applying HFC-134a, only 25% (as of 2004) are being released in the manufacturing year (First Year ER: 25%), whereas 75% remain in the XPS product. Operating emissions amount to 0.66% per year over the use-phase. However, it must be mentioned that only a certain fraction of annual XPS output containing HFC-134a increases the domestic bank because about 75% are exported. (HFCs in exported XPS foam products have to be attributed to banks in importing countries).

"Without measures" supposes a one-to-one conversion from the HCFC quantity used in 1998 to HFCs, the latter being half HFC-134a and half HFC-152a.

"With measures through 2003": In the end of the actual HCFC phase-out, which lasted from 1998 to 2001, a considerable fraction of XPS panels was already manufactured without halogenated blowing agents. Therefore, annually applied HFC quantities are significantly lower than in the first scenario. Extrapolating the real 134a/152a ratio of 2001, by 2010 some 2343 t HFC-134a and about 1673 t HFC-152a might be used. By 2020, these quantities are 2856 t (HFC-134a) and 2040 t (HFC-152a), respectively.

Although "EU legislation 2007" does not provide for measures in case of XPS foam so that the denotation of the third scenario must be taken with reservation, this scenario reflects some alterations vs. the second scenario. The changes arose in the XPS producers' discussion over the goals of a possible self-commitment: Existing plants go on applying HFC-134a as they do in the second scenario. However, the use of HFC-152a is gradually reduced to zero by 2020. Alternative solution to 152a is CO_2, at least by 90%. Ten percent of the XPS products, for which HFC-152a was used in the second scenario, continue to be blown with HFC-134a. These additional HFC-134a containing panels are exported 75%.

Scenario "With further measures": this scenario assumes even the application of HFC-134a to be reduced gradually down to 20% by 2010 (difficult cases). By 2020 use of HFC-134a is ceased. Thus, only use-phase emissions occur after 2020.

1.4.2. PU Foam

Generally, in PU rigid foam 3% annual growth in consumption is assumed from 2004 to 2010, which is followed by a constant consumption level (growth rate 0%) as of 2011. The new blowing agent is HFC-365mfc, strictly speaking a blend of 93% HFC-365mfc and 7% HFC-227ea. The competing blowing agent HFC-245fa is not considered separately, but it is supposed to be included in the quantities of the former. HFC-134a had been used in rigid foam for sandwich panels until 2004 when it was ceased. After 2004, it is still in use only in the small sector of PU integral skin. Here, it shares the market with HFC-365mfc at a ratio of 3:1 for the time being.

"Without measures from 1999": The large PU sectors of refrigerators, sandwich panels (all but one plant), and insulating roof panels had changed over to hydrocarbons (pentanes) as blowing agents, by 1998. The assumption is that the remaining HCFC quantity (estimated at 3,000 t/y in 1998) is completely replaced by new HFCs (HFC-365mfc with 227ea admixture). HFC-134a is kept on being used in sandwich panels (one plant). In addition, HFCs are permanently applied to foaming of integral skin, in a quantity of 80 t/y: 60 t/y HFC-134a and 20 t/y HFC-365mfc.

"With measures through 2003": Between 1998 and 2003, further HCFC applications changed over to hydrocarbons. At the end of 2003, only half the 1998 quantity of HCFC-141b (1,500 t/y) was used. This reduced quantity is assumed to be converted one-to-one to HFC-365mfc in PU rigid foam from 2004 onwards. Annual growth in consumption is 3%, until 2010. (Use of HFC-134a for rigid foam for sandwich panels was ceased in the course of 2003). Application fields of HFC-365mfc are discontinuously manufactured insulation boards (small series), block foam, insulation of pipes (district heating + injected foam), and particularly spray foam. HFC use for integral skin is the same as in scenario "Without measures".

In PU rigid foam, average First Year Emissions are comparably high due to the high share of openly applied spray foam in the product mix with some 15%. By that, manufacturing emissions are higher than in the first scenario (12.5%), where the relative part of highly emissive spray foam is smaller. Use-phase emission rate from the bank amounts to 1%, generally. In foaming of integral skin, the blowing agent is completely released upon manufacture.

"EU legislation 2007" does not address PU rigid foam. Hence, there is no difference of the third vs. the second scenario.

"With further measures": There is no one-to-one switch from HCFC-141b to new, liquid HFCs, but only a partial conversion. No HFCs are used for insulation of pipes. In discontinuous panels (small series) HFCs are used only 20% compared with the two preceding scenarios. From 2008 onwards, growth in HFC consumption for this application no longer takes place, and from 2015 onwards HFCs are no longer used at all. In spray and block foam introduction of HFCs is halved vs. the scenario "With measures through 2003". As of 2008, consumption of HFCs does not grow any longer, and from 2015 onwards the level is halved again. Foaming of integral skin is gradually done without HFCs, beginning in 2008 and completed in 2014.

1.4.3. One Component Foam (OCF)

In Scenario "Without measures from 1999" conditions of 1998 are kept constant in the long term: domestic market amounts to 26 million cans, HFC content per can is 70 grams, and the 134a/152a ratio is 60:40. Domestic manufacture figures 16 million cans, with 1.5 grams propellant (only 134a) per can being released on filling.

In contrast to the first scenario, in "With measures through 2003" domestic market amounts to only 22 million cans (average of 1995-2003). HFC content per 750 ml can keeps at the 2003 status quo level of only 47 grams. Likewise, the 2003 ratio between 134a and 152a of 44:56 is kept. (Domestic filling: 26 million cans, as in 2003).

Scenario "EU legislation 2007" takes valid (as of 2008) the prohibition of placing on the market for OCF (one-component foam) in accordance with the F-Gas Regulation "except when required to meet national safety standards". For simplicity, this scenario assumes HFCs to be applied furthermore there where according to manufacturers' indications the propellant has to be hardly inflammable, for safety reasons. This quantity had been estimated by manufactures at 5% of the 2003 domestic market (e.g. for underground work). Pursuant to this indication, a reduction of HFC containing foam cans is assumed in domestic sales and production, compared with the second scenario. Alternative solutions are inflammable propellants like hydrocarbons, etc. Nevertheless, the fire protection requirements (class B2) are met by means of altered formulations. HFC content and HFC ratio remain the same as in the second scenario.

Scenario "With further measures": Sales and production figures are the same as before. Even the 5% OCF cans with HFCs prove to be not necessary. They are replaced by cans with inflammable propellants (propane, butane, dimethyl ether). In case of doubt, it is possible to use two-component foam (without HFCs). From 2010 onwards, HFCs are applied neither in production, nor in use.

1.5 By-product Emissions of HFC-23

For confidentiality, absolute figures are not given here.

Scenario I assumes the emissions of 1998 (which were below the 1995 level) to be constant until 2020. Production of HCFC-22 as feedstock for fluorinated plastics (PTFE) is not subject to time limitation, in contrast to HCFC as refrigerant.

In the second and third scenario emissions are substantially lower, in both cases at the level of 2003. It amounts to only 17.5% of the 1998 initial level in scenario I, and is the same for 2010 and 2020.

The last scenario supposes success in halving the 2003 emissions by 2010. This reduced value is assumed constant until 2020.

2. PFC Emissions 2010 and 2010

2.1 Aluminium Industry

"Without measures from 1999": Basis of this scenario is the 1997 self-commitment of the German primary aluminium industry, which intended to halve specific CF_4 emissions per tonne Al to 0.22 kg by 2005. The scenario keeps this value constant for the time after and multiplies it by the annual metal output of 583,872 t, which was the average smelter production in 1995-1998.

The three following scenarios are based on higher metal output, namely on 653,000 t/y. This value averages over the years 2000 to 2003. The production capacity of smelters in Germany remains constant at the level of 2003. Reduction in capacity as discussed repeatedly is not considered.

Scenario "With measures through 2003" as well as scenario "EU legislation 2007" (the latter does not address aluminium production) extrapolate the average specific CF_4 values per tonne aluminium of 2000-2003. Pursuant to data from the Federation of German Aluminium Industries, the average emission coefficient over all smelters figured only 0.084 kg/t Al.

On grounds of the successful PFC emission reduction in the aluminium industry until 2004, the "With further measures" scenario assumes continuation of the reduction process. It supposes all domestic smelters to introduce the emission-reducing point feeding technology by 2009 at the latest, so that the specific emission factor CF_4 per tonne aluminium is just 0.067 kg, both in 2010 and in 2020.

2.2 Refrigerants

All scenarios share the common assumption that R-218 (component of service refrigerants) banked in old equipment will be removed by 2013 so that there will be no 2020 emissions. In 2010, still some operating emissions (15% ER) and disposal emissions (30% ER) are expected to occur. Emissions do not differ by individual scenarios.

The second PFC, R-116, is a component of the low-temperature refrigerant blend R-508B which is used in new equipment of industrial and commercial refrigeration. With respect to used quantities, specific emission factors, and shares of natural refrigerants, the four scenarios are identical to those that are described above for HFC refrigerants in commercial and industrial refrigeration.

2.3 Manufacture of Printed Circuit Boards

No different scenarios are assessed. In each of the four scenarios the same input quantity of 2.4 t/y is assumed, from which a fraction of 2 t/y is released to the atmosphere.

Table 12 PFC Emissions 1995, 2010, and 2020 (t)

Sectors	Initial values	Without measures from 99		With measures through 2003		EU legislation 2007		With further measures	
	1995	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**
Aluminium Production	230	141	141	60	60	60	60	48	48
Semiconductor Manuf.	23	85	221	20	20	20	20	20	20
Manufacture of PCB	2	2	2	2	2	2	2	2	2
Refrigeration	1.2	8.5	5.6	8.5	5.6	6.6	3.3	6.5	2.4
Total	**256**	**237**	**370**	**91**	**88**	**89**	**86**	**77**	**73**

Table 13 PFC Emissions 1995, 2010, and 2020 (million t CO_2 equivalent)

Sectors	1995 Baseline	Without measures from 99		With measures through 2003		EU legislation 2007		With further measures	
	1995	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**
Aluminium Production	1.552	0.953	0.953	0.408	0.408	0.408	0.408	0.325	0.325
Semiconductor Manuf.	0.177	0.682	1.769	0.159	0.159	0.159	0.159	0.159	0.159
Manufacture of PCB	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
Refrigeration	0.008	0.072	0.051	0.072	0.051	0.054	0.030	0.054	0.022
Total	**1.750**	**1.720**	**2.786**	**0.652**	**0.631**	**0.634**	**0.610**	**0.551**	**0.519**

2.4 Semiconductor Industry

Introductory remark: Since 2000 the rise in PFC emissions from semiconductor industry has substantially slowed down. While emissions of newly PFCs like C_3F_8 and C_4F_8 are increasing, emissions of the traditional etching gases C_2F_6 and CF_4 tend to decrease.

In the first scenario "Without measures from 1999", the conditions of the 1995-1998 period are extrapolated to the future. For each PFC type annual emission growth rate of 10% is applied to its average 1995-1998 emissions, until 2010 and 2020, respectively. 10% was the real annual growth over that 1995-1998 baseline period.

All the three scenarios "With measures through 2003", "EU legislation 2007", and "With further measures" assume a drop in emissions by 10% below the 1995 baseline year emissions, by the year 2010. This assumption follows the 1999 global emission reduction agreement signed by the World Semiconductor Council, which the German semiconductor industry has joined. Independently, since 1999 German manufacturers have initiated and implemented emission abatement and process optimization measures. From 2010 to 2020, constant emission level is assumed.

3. SF_6 Emissions 2010 and 2010

3.1 Transmission and Distribution of Electricity

Electrical equipment for power transmission and distribution comprise both switchgear in high and medium voltage, and associated components like instrument transformers and bushings. All scenarios assume for domestic SF_6 consumption (high export quota!) annual growth of 2.5%, which predominantly results from medium voltage equipment. Domestic SF_6 bank is supposed to rise from 1.5 to 1.9 million t over the 2003-2010 periods. Afterwards, disposal of old equipment starts on a large scale so that the total bank will go on growing to just 2.1 million t over the next decade until 2020. Then, half the SF_6 quantity is banked in high voltage equipment (HV), and the other half in medium voltage equipment (MV).

The first scenario "Without measures from 1999" keeps the emission rates of 1998 constant. Factory and assembly gas losses in HV and MV switchgear remain at 6.1 and 2.0%, respectively, in relation to domestic consumption. In components (partially open applications) absolute 14 t/y continue to be lost, which is in relative terms 28% emission rate of annual consumption. Operating bank emissions amount to 0.872% (HV) and 0.1% (MV). Disposal emissions at end of life are calculated 2%. This low value is possible because efficient end-of-life treatment, called "ReUse", can be taken for granted since the mid nineties.

"With measures through 2003": Emission rates had been lowered through 2003, and these values are kept constant for the future. Thus, factory and assembly losses amount both in HV and in MV to only 1.5%, each, absolute emissions from components are 11.3 t/y, instead of 14 t/y. This is 22% in relative terms. Operating bank emissions are 0.82%. Disposal emissions at end-of-life are the same as in the first scenario.

EU legislation does not affect equipment made or installed in Germany. Therefore, the emission factors are identical to those in the second scenario.

Scenario "With further measures" regards those goals as feasible, which the 2005 renewed and extended self-commitment of German industry, operators, and SF_6 producer proclaims. Operating emissions gradually decrease to 0.6% in HV, and keep their low level of 0.1% in MV. Factory and site assembly losses remain at 1.5% in switchgear. Owing to practical termination of open applications in components, their factory losses drop from 22% to 3%. Total domestic emissions fall below 17 t/y in 2020 (after 43 t/y in 1995).

3.2 Other Electrical Equipment

Here, primarily emissions from particle accelerators in research, industry, and medicine are accounted for, together with emissions from manufacture of power capacitors. For particle accelerators in all scenarios unchanged size of bank and constant operating emission rate (6%) are assumed.

Table 14 SF_6-Emissions 1995, 2010, and 2020 (t)

Sectors	1995 Baseline	Without measures from 1999		With measures through 2003		EU Legislation 2007		With further Measures	
	1995	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**
Transm. + Distr. of Electricity	43.4	47.5	47.7	29.7	30.0	29.7	30.0	22.5	16.6
Other electrical applications	5.2	17.0	17.0	6.0	6.0	6.0	6.0	5.0	5.0
Magnesium Casting	7.7	40.9	70.8	33.1	53.1	4.0	7.0	0	0
Soundproof Glazing	107.9	127.0	198.5	95.3	162.0	84.3	149.1	84.3	149.1
Car Tires	110.0	30	30	2.5	2.5	0	0	0	0
Sport Shoes/AWACS/Glass fibre	18.5	10	10	10	10	10	10	10	10
Tracer gas/Aluminium Cleaning	1.0	40.5	40.5	40.5	40.5	40.5	40.5	0.5	0.5
Other	9.0	16.6	27.2	10.4	10.4	10.4	10.4	10.4	10.4
Total	**303**	**329**	**442**	**228**	**3145**	**185**	**253**	**133**	**192**

Table 15 SF_6-Emissions 1995, 2010, and 2020 (million t CO_2 equivalent)

Sectors	1995 Baseline	Without measures from 1999		With measures through 2003		EU Legislation 2007		With further Measures	
	1995	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**
Transm. + Distr. of Electricity	1.036	1.135	1.140	0.711	0.716	0.711	0.716	0.537	0.398
Other electrical applications	0.125	0.405	0.405	0.142	0.142	0.142	0.142	0.118	0.118
Magnesium Casting	0.185	0.977	1.692	0.791	1.269	0.096	0.167	0	0
Soundproof Glazing	2.578	3.036	4.745	2.279	3.872	2.015	3.564	2.015	3.564
Car Tires	2.629	0.717	0.717	0.060	0.060	0	0	0	0
Sport Shoes/AWACS/Glass fibre	0.442	0.239	0.239	0.239	0.239	0.239	0.239	0.239	0.239
Tracer gas/Aluminium Cleaning	0.024	0.968	0.968	0.968	0.968	0.968	0.968	0.012	0.012
Other	0.216	0.397	0.650	0.248	0.248	0.248	0.248	0.248	0.248
Total	**7.235**	**7.875**	**10.556**	**5.438**	**7.514**	**4.418**	**6.045**	**3.169**	**4.579**

In case of highly emissive manufacture of power capacitors scenario "Without measures from 1999" extrapolates the historic emissions of 1998 to the future. In 2002, the manufacturers decided to cease the production by 2010; actually, since then decreasing annual emissions can be observed. Based on this fact, both scenario "With measures through 2003" and scenario "EU legislation 2007" assume emissions of only 1 t/y for 2010 and 2020, resulting from service. Even this quantity is dispensed with in the last scenario ("With further measures").

3.3 Magnesium Casting

Following the 1995-2003 trends, all scenarios assume constant increase in metal output by 3,000 t/y, which leads to 41,000 t in 2010 and 71,000 t in 2020, respectively.

In scenario "Without measures from 1999" the coefficient "kg SF_6 per tonne magnesium produced" remains constant at the historic 1998 level which was exactly 1.

Scenario "With measures through 2003" extrapolates the 2000-2003 rises in SF_6 consumption unchanged to the future. This increase between 2000 and 2003 amounted to 2,000 kg per year. The SF_6 coefficient per t Mg is assumed 0.79 in 2010 and 0.72 in 2020. (2003: 0.83).

In scenario "EU legislation 2007" SF_6 emissions drop substantially because the upcoming Regulation intends to permit use of SF_6 only in foundries below an annual consumption level of 850 kg, from 2008 onwards.

Scenario "With further measures" exceeds the third scenario by supposing that as of 2010 at the latest SF_6 is no longer used at all as a cover gas, not even in small foundries. Appliers of more than 850 kg SF_6 then will use other cover gases such as HFC-134a (75%) and SO_2 or hydro-fluoro-ethers (25%). To that effect the HFC scenario "EU legislation 2007" has to consider a corresponding rise in HFC-134a emissions (from 0 to 11 and 17 t/y); in HFC-scenario "With further measures" the values are 12 and 20 t/y. (It must be borne in mind that the specific input of HFC-134a is only half the former SF_6 quantity).

3.4 Soundproof Glazing

In all four scenarios for 2010 and 2020, disposal emissions upon decommissioning of panes are not only constantly high with 67 and 143 t/y, respectively, but they make up more than half of the overall domestic SF_6 emissions in each scenario by 2020. Therefore, until 2020 efficiency of any measures to reduce substantially SF_6 emissions is limited because gas recovery from old soundproof panes is deemed unfeasible for cost reasons. Nevertheless, even prior to 2020 there are measures possible that cut off new consumption of SF_6 (intended by EU legislation) and thus manufacturing emissions. As a result of such a stop, bank emissions would be lowered slightly, too.

Scenario "Without measures from 1999" keeps the 1998 annual new consumption of 111 t constant in the long term. This quantity corresponds to a ratio between SF_6 and argon in the pane interspace of 30:70.

Scenario "With measures through 2003" assumes SF_6 emissions from new consumption to be constant for the future at 10 t p.a., which is the (reduced) level of 2003.

Annual 10 t filling emissions cease to occur in the two following scenarios "EU legislation 2007" and "With further measures", where new consumption is assumed to be banned from 2007 onwards.

3.5 Car Tires

Consumer behaviour to tire filling, once the largest single SF_6 emission source, has significantly changed. Scenario "Without measures from 1999", which extrapolates the 1998 consumption unaltered, arrives at 30 t emissions yearly. Scenario "With measures through 2003" extrapolates new consumption of 2003, which is only 2.5 t p.a. In scenario "EU legislation 2007", (disposal) emissions no longer arise by 2010 because of 2007 use prohibition. The last scenario "With further measures" is identical to the third scenario with likewise zero emissions by 2010.

3.6 Sport Shoe Soles/AWACS Radar/Glass Fibres

For confidentiality, emissions are not distinguished into manufacturing, operating, and disposal emissions. Moreover, all emissions from (i) sport shoe soles, from (ii) AWACS military aircraft radar systems (as far as attributable to Germany), and from (iii) fluoro doping of glass fibres are taken together. This approach is hypothetical insofar as by 2010 or by 2020 emissions from sport shoe soles occur in none of the four scenarios, not even in scenario I "Without measures from 1999". This is why already in 1998 manufacturer Nike had started replacing SF_6 by nitrogen in shoe soles, throughout the world and gradually. Present state of Nike's phase-out programme makes SF_6 emissions from this source by 2010 unlikely.

The projected emissions come from military aircraft radar and from manufacture of glass fibres. The latter, fluoro doping of glass fibres for network cables and that like, is highly emissive, and is of relevance in Germany since 2002. For lack of better forecasting abilities all the four scenarios assume the previous annual emissions to be constant for the near future. Long run constancy is also supposed for emissions caused by AWACS radar systems in operation over Germany.

3.7 Tracer Gas and Aluminium Cleaning

Emissions from the application of SF_6 as tracer gas are kept equal in all scenarios, which is to say at the low average level over the years from 1995 to 2003.

Before the mid nineties, a small fraction of SF_6 (0.5-2%) had been added to an inert gas mixture to form a cleaning agent for secondary aluminium smelts to be used prior to casting. Since 1998, however, in casting of special alloys application of pure SF_6 has been expanded substantially to an unexpectedly high level of 45 t in 2003. For lack of better knowledge, consumption has been set equal to emissions so far. The first three scenarios for 2010 and 2020 preliminarily assume annual emissions of 40 t from this application (average over 2002-2003) as long as no plans become known that SF_6 is dispensed with in the foundries. In contrast to the first three scenarios, scenario "With further measures" supposes a climate-neutral solution to be found for aluminium cleaning by 2010.

3.8 Semiconductor Industry

In case of SF_6 the same scheme as in HFC-23 and PFCs is applied.

3.9 Other

In addition to fugitive emissions from SF_6 production, here are several small applications listed, each of which is very small in itself. In all the four scenarios constant emissions of 10 t per year are assumed.

III. Annex Tables

En detail, the following twelve pages list all historic F-gas emissions of 1995 and from 1998 to 2003 as well as the emissions projected for 2010 and 2020 by the aforementioned four different scenarios.

There is not only a subdivision into individual sectors, but the individual sectors themselves are further broken down into different kinds of emissions, mostly into manufacturing, bank, and disposal emissions.

To the left, on the pages with even numbers, historic emissions are reproduced, i.e. those emissions that occurred up to and including 2003. To the right, on the pages with odd numbers, forecasted emission figures for 2010 and 2020 are listed.

It should be mentioned that for confidentiality some emission figures cannot be shown detailed but must be presented aggregated.

	A	B	C	D	E	F	G	H	I	J	L
1											
2		**Table Individual F-Gas Emissions**									
3											
4	**HFCs**		1995		1998	1999	2000	2001	2002	2003	
5	**Stationary Refrig./AC**										
6	**Industrial Refrigeration**										
7	**Operating Emiss. [t]**										
8	HFC-134a		4		34	47	57	68	78	88	
9	R-404A		3		38	59	80	102	123	144	
10	R-407C		1		4	5	8	10	12	14	
11	HFC-23		0.7		2.1	2.7	3.4	4.0	5	5	
12	HFC-227		0.1		1.3	1.8	2.3	2.8	3.4	3.9	
13	PFC-116				0.1	0.2	0.2	0.3	0.4	0.4	
14	**Disposal Emiss. [t]**										
15	HFC-134a									2.40	
16	R-404A									1.50	
17	R-407C									0.90	
18	HFC-23									0.90	
19	HFC-227									0.08	
20	PFC-116									0.00	
21	**Manuf. Emiss. [t]**										
22	HFC-134a		0.1		0.3	0.2	0.2	0.2	0.2	0.2	
23	R-404A		0.1		0.4	0.5	0.5	0.5	0.5	0.5	
24	R-407C		0.0		0.0	0.0	0.0	0.0	0.0	0.0	
25	HFC-23		0.0		0.0	0.0	0.01	0.0	0.0	0.0	
26	Subtotal Emiss. w/o PFC		9		80	117	152	187	222	262	
27	*Kilotonnes CO2 equiv.*		*26*		*203*	*300*	*396*	*492*	*588*	*701*	
28	**Commercial Refriger.**		1995		1998	1999	2000	2001	2002	2003	
29	**Operating Emiss. [t]**										
30	HFC-134a		19		153	200	233	258	283	303	
31	R-404A		18		167	234	298	361	424	486	
32	R-407C		0		1	2	4	7	11	15	
33	HFC-23		0.1		0.4	0.9	1.6	2.3	3.0	3.7	
34	PFC-116		0		0.4	0.7	1.0	1.4	1.7	2.1	
35	PFC-218		1.2		7.2	9.2	10.1	10.8	11.4	11.6	
36	HFC-152a		0.5		10.7	13.7	15.0	15.4	15.4	14.9	
37	HFC-125		15		52	59	62	62.7	62.9	62.5	
38	**Disposal Emiss. [t]**										
39	HFC-134a									24.3	
40	R-404A									5.0	
41	R-407C										
42	HFC-23									0.3	
43	PFC-116										
44	PFC-218									0.3	
45	HFC-152a									2.0	
46	HFC-125									1.8	
47	**Manuf. Emiss. [t]**										
48	HFC-134a		0.4		1.0	0.8	0.6	0.6	0.6	0.6	
49	R-404A		0.5		1.4	1.4	1.3	1.3	1.3	1.3	
50	R-407C				0.0	0.0	0.1	0.1	0.1	0.1	
51	HFC-23		0.0		0.0	0.0	0.0	0.0	0.0	0.0	
52	PFC-116				0.0	0.0	0.0	0.0	0.0	0.0	
53	Subotal Emiss. w/o PFCs		54		386	512	615	708	801	921	
54	*Kilotonnes CO2 equiv.*		*130*		*901*	*1,209*	*1,480*	*1,732*	*1,985*	*2,283*	
55	**Stat. AC + Heat Pumps**		1995		1998	1999	2000	2001	2002	2003	
56	**Operating Emiss. [t]**										
57	HFC-134a		8.7		46.50	57.05	64.44	71.59	78.15	84.76	
58	R-407C		0.02		2.27	8.74	20.36	35.26	50.77	66.46	
59	R-410A				0.01	0.05	0.17	0.77	1.79	3.26	
60	R-404A		0.01		0.10	0.14	0.19	0.25	0.33	0.43	
61	**Disposal Emiss. [t]**										
62	HFC-134a										
63	R-407C										
64	R-410A										
65	R-404A										

	M	N	O	P	Q	R	S	T	U	V	W
1											
2											
3											
4	2010	2020		2010	2020		2010	2020		2010	2020
5											
6											
7	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
8	114	114		108	108		92	89		91	55
9	297	297		215	215		190	184		188	115
10	21	21		21	21		19	18		18	11
11	7	6.7		7	6.7		5.9	6		5.8	4
12	5.1	5.1		5.1	5.1		4.5	4.4		4.4	2.7
13	0.7	0.7		0.7	0.7		0.6	0.6		0.6	0.4
14											
15	49	49		44	44		30	30		30	22.2
16	127	127		92	92		61	61		61	46.0
17	9	9		9	9		6	6		6	4.5
18	2.9	2.9		2.9	2.9		1.9	1.9		1.9	1.4
19	2.2	2.2		2.2	2.2		1.5	1.5		1.5	1.1
20	0.3	0.3		0.3	0.3		0.2	0.2		0.2	0.2
21											
22	0.2	0.2		0.2	0.2		0.2	0.2		0.2	0.1
23	0.6	0.6		0.5	0.5		0.5	0.5		0.3	0.2
24	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0
25	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0
26	635	635		507	507		412	402		408	263
27	*1,774*	*1,774*		*1,378*	*1,378*		*1,125*	*1,097*		*1,114*	*720*
28	2010	2020		2010	2020		2010	2020		2010	2020
29	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
30	252	252		252	252		155	131		154	92
31	613	613		613	613		373	313		371	217
32	46	49		46	49		28	25		28	17
33	7.2	7.2		7.2	7.2		5.4	5.0		5.4	3.5
34	4	4		4	4		2.1	1.8		2.1	1.2
35	1.5			1.5			1.5			1.5	
36											
37	0.7			0.7			0.7			0.7	
38											
39	89	89		89	89		60	60		60	54
40	201	201		201	201		134	134		134	121
41	8	15		8	15		5	10		5.0	9
42	4.3	4.3		4.3	4.3		2.9	2.9		2.9	2.6
43	1.1	1.1		1.1	1.1		0.7	0.7		0.7	0.6
44	1.4			1.4			1.4			1.4	
45											
46	1.8			1.8			1.8			1.8	
47											
48	0.6	0.6		0.6	0.6		0.6	0.6		0.54	0.30
49	1.3	1.3		1.3	1.3		1.3	1.3		1.09	0.67
50	0.1	0.1		0.1	0.1		0.1	0.1		0.09	0.05
51	0.0	0.0		0.0	0.0		0.0	0.0		0.03	0.01
52	0.0	0.0		0.0	0.0		0.0	0.0		0.01	0.00
53	1,226	1,234		1,226	1,234		767	682		764	516
54	*3,329*	*3,338*		*3,329*	*3,338*		*2,091*	*1,856*		*2,082*	*1,403*
55	2010	2020		2010	2020		2010	2020		2010	2020
56	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
57	120.6	142.4		120.6	142.4		104.7	118.8		104.3	106.9
58	171.3	214.9		171.3	214.9		152.7	180.9		151.2	134.5
59	28.6	68.0		28.6	68.0		24.4	57.8		24.3	52.1
60	1.5	2.9		1.5	2.9		1.3	2.3		1.3	1.7
61											
62	11.7	39.7		11.7	39.7		7.8	26.5		7.8	26.5
63	56.8	89.9		56.8	89.9		37.8	57.1		37.8	55.1
64	2.2	65.8		2.2	65.8		1.5	37.6		1.5	35.6
65	0.3	1.8		0.3	1.8		0.2	1.0		0.2	1.0

	A	B	C	D	E	F	G	H	I	J	L
66	**Manuf. Emiss. [t]**										
67	HFC-134a		0.02		0.02	0.02	0.02	0.02	0.02	0.02	
68	407C				0.03	0.05	0.08	0.09	0.09	0.09	
69	Subtotal Emiss. w/o PFCs		9		49	66	85	108	131	155	
70	*Kilotonnes CO2 equiv.*		*11*		*64*	*88*	*116*	*149*	*183*	*219*	
71	**Househ. Refr. HFC-134a t**		1.2		1.2	1.3	1.3	1.3	1.3	1.3	
72	*Househ. Ref. kt CO2 eq*		*1.6*		*1.6*	*1.6*	*1.7*	*1.7*	*1.7*	*1.7*	
73											
74	**Subt. HFC Stationary**		1995		1998	1999	2000	2001	2002	2003	
75	Emiss. w/o PFCs [t]		73		516	696	854	1,004	1,155	1,339	
76	*Kilotonnes CO2 equiv.*		*169*		*1,170*	*1,599*	*1,994*	*2,375*	*2,758*	*3,205*	
77											
78	**Mobile AC/Refriger.**										
79	**Passenger Car AC**		1995		1998	1999	2000	2001	2002	2003	
80	**Operating Emiss. [t]**										
81	HFC-134a		129		555	765	979	1,185	1,385	1,576	
82	HFC-152a										
83	**Disposal Emiss. [t]**										
84	HFC-134a								10	30	
85	HFC-152a										
86	**Manuf. Emiss. [t]**										
87	HFC-134a		3		8	9	9	10	10	10	
88	HFC-152a										
89	Subtotal Emiss. [t]		133		563	774	988	1,195	1,405	1,616	
90	*Kilotonnes CO2 equiv.*		*172*		*732*	*1,007*	*1,284*	*1,553*	*1,826*	*2,101*	
91	**Truck Air Conditioners**		1995		1998	1999	2000	2001	2002	2003	
92	**Operating Emiss. [t]**										
93	HFC-134a		4		19	28	38	49	59	70	
94	**Disposal Emiss. [t]**										
95	HFC-134a										
96	**Manuf. Emiss. [t]**										
97	HFC-134a		0.08		0.19	0.21	0.24	0.27	0.27	0.30	
98	Subtotal Emiss. [t]		4		19	28	39	49	59	70	
99	*Kilotonnes CO2 equiv.*		*5*		*25*	*37*	*50*	*64*	*77*	*91*	
100	**Bus Air Conditioners**		1995		1998	1999	2000	2001	2002	2003	
101	**Operating Emiss. [t]**										
102	HFC-134a		12		32	39	46	53	60	66	
103	**Disposal Emiss. [t]**										
104	HFC-134a									3.3	
105	**Manuf. Emiss. [t]**										
106	HFC-134a		0.02		0.04	0.04	0.04	0.04	0.03	0.04	
107	Subtotal Emiss. [t]		12		32	39	46	53	60	70	
108	*Kilotonnes CO2 equiv.*		*16*		*42*	*50*	*60*	*69*	*78*	*91*	
109	**Agricult. Machines AC**		1995		1998	1999	2000	2001	2002	2003	
110	**Operating Emiss. [t]**										
111	HFC-134a		3		12	16	20	24	29	34	
112	**Disposal Emiss. [t]**										
113	HFC-134a										
114	**Manuf. Emiss. [t]**										
115	HFC-134a		0.1		0.1	0.1	0.1	0.2	0.2	0.2	
116	Subtotal Emiss. [t]		3		13	16	20	25	29	34	
117	*Kilotonnes CO2 equiv.*		*4*		*16*	*21*	*26*	*32*	*38*	*45*	
118	**Railcar AC**		1995		1998	1999	2000	2001	2002	2003	
119	**Operating Emiss. [t]**										
120	HFC-134a		5.2		12	15	17	20	23	25	
121	**Disposal Emiss. [t]**										
122	HFC-134a										
123	**Manuf. Emiss. [t]**										
124	HFC-134a		0.018		0.04	0.03	0.04	0.04	0.04	0.02	
125	Subtotal Emiss. [t]		5.3		12	15	17	20	23	25	
126	*Kilotonnes CO2 equiv.*		*7*		*16*	*19*	*22*	*26*	*30*	*32*	

	M	N	O	P	Q	R	S	T	U	V	W
66											
67	0.02	0.02		0.02	0.02		0.02	0.02		0.01	0.01
68	0.09	0.09		0.09	0.09		0.09	0.09		0.07	0.05
69	393	626		393	626		331	482		328	413
70	*579*	*948*		*579*	*948*		*487*	*727*		*484*	*623*
71	1.38	1.38		1.38	1.38		1.38	1.38		1.38	1.38
72	*1.8*	*1.8*		*1.8*	*1.8*		*1.8*	*1.8*		*1.8*	*1.8*
73											
74	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
75	2,255	2,496		2,128	2,368		1,511	1,567		1,501	1,194
76	*5,684*	*6,062*		*5,288*	*5,666*		*3,704*	*3,683*		*3,681*	*2,748*
77											
78											
79	2010	2020		2010	2020		2010	2020		2010	2020
80	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
81	2,692	2,812		2,692	2,812		2,580	938		2,580	938
82							22	375			
83											
84	604	755		604	755		403	453		403	453
85								9			
86											
87	10	10		10	10		7	0		7	0
88							1	2			
89	3,306	3,577		3,306	3,577		3,013	1,777		2,990	1,391
90	*4,297*	*4,650*		*4,297*	*4,650*		*3,890*	*1,862*		*3,887*	*1,808*
91	2010	2020		2010	2020		2010	2020		2010	2020
92	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
93	155	223		155	223		155	211		155	134
94											
95	19	37		19	37		13	25		13	25
96											
97	0.42	0.51		0.42	0.51		0.42	0.51		0.42	0
98	175	261		175	261		168	237		168	159
99	*227*	*339*		*227*	*339*		*219*	*308*		*219*	*207*
100	2010	2020		2010	2020		2010	2020		2010	2020
101	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
102	92	104		92	104		92	104		92	65
103											
104	13	17		13	17		8	11		8	11
105											
106	0.05	0.05		0.05	0.05		0.05	0.05		0.05	0
107	105	120		105	120		100	115		100	76
108	*136*	*157*		*136*	*157*		*130*	*149*		*130*	*99*
109	2010	2020		2010	2020		2010	2020		2010	2020
110	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
111	57	64		57	64		57	64		57	35
112											
113	7	12		7	12		5	8		5	8
114											
115	0.3	0.3		0.3	0.3		0.3	0.3		0.3	0
116	64	76		64	76		62	72		62	43
117	*83*	*98*		*83*	*98*		*80*	*93*		*80*	*56*
118	2010	2020		2010	2020		2010	2020		2010	2020
119	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
120	25	29		25	29		25	29		25	20
121											
122		2			2			1.6			1.6
123											
124	0.02	0.02		0.02	0.02		0.02	0.02		0.02	0
125	25	31		25	31		25	30		25	22
126	*32*	*41*		*32*	*41*		*32*	*40*		*32*	*28*

	A	B	C	D	E	F	G	H	I	J	L
127	**Ship Air Conditioning**		1995		1998	1999	2000	2001	2002	2003	
128	**Operating Emiss. [t]**										
129	HFC-134a		0		0.2	0.4	0.7	0.9	1.1	1.3	
130	**Disposal Emiss. [t]**										
131	HFC-134a										
132	**Manuf. Emiss. [t]**										
133	HFC-134a		0		0.1	0.1	0.1	0.1	0.1	0.1	
134	Subtotal Emiss. [t]		0.0		0.3	0.5	0.7	1.0	1.2	1.4	
135	*Kilotonnes CO2 equiv.*		*0*		*0.4*	*0.7*	*1.0*	*1.3*	*1.6*	*1.9*	
136	**Refrigerated Vehicles**		1995		1998	1999	2000	2001	2002	2003	
137	**Operating Emiss. [t]**										
138	HFC-134a		2		7	10	12	13	15	16	
139	404A		7		17	21	25	29	33	35	
140	410A		0.2		2	2	3	3	4	5	
141	152a v. 401B				0.2	0.2	0.25	0.25	0.25	0.22	
142	218 v. 413A				0.1	0.2	0.23	0.23	0.23	0.20	
143	**Disposal Emiss. [t]**										
144	HFC-134a									2.7	
145	404A									5.6	
146	410A										
147	152a v. 401B									0.1	
148	218 v. 413A									0.1	
149	**Manuf. Emiss. [t]**										
150	HFC-134a		0.01		0.03	0.03	0.02	0.02	0.02	0.02	
151	404A		0.01		0.01	0.01	0.01	0.01	0.01	0.01	
152	410A		0.00		0.00	0.00	0.00	0.00	0.00	0.00	
153	Subotal Emiss. w/o PFC		9		26	34	40	46	52	64	
154	*Kilotonnes CO2 equiv.*		*25.49*		*68.222*	*86.196*	*102.53*	*117.535*	*132.873*	*165.32*	
155	**Reefer Container**		1995		1998	1999	2000	2001	2002	2003	
156	**Operating Emiss. [t]**										
157	HFC-134a		3		11.21	13.9	16.6	19.2	22.1	25.4	
158	404A				0.3	0.6	0.9	1.3	1.7	2.3	
159	**Disposal Emiss. [t]**										
160	HFC-134a										
161	404A										
162	Subtotal Emiss. [t]		3.2		11.5	14.5	17.5	20.5	23.8	27.6	
163	*Kilotonnes CO2 equiv.*		*4*		*16*	*20*	*24*	*29*	*34*	*40*	
164	**Subt. HFCs mobile**										
165	Emiss. w/o PFC [t]		170		677	921	1,168	1,409	1,653	1,908	
166	*Kilotonnes CO2 equiv.*		*234*		*915*	*1,241*	*1,571*	*1,892*	*2,218*	*2,567*	
167	**Other HFC Use**										
168	**One-Component Foam**		1995		1998	1999	2000	2001	2002	2003	
169	First Year Emiss. [t]										
170	HFC-134a		1080		1092	780	719	660	425	381	
171	HFC-152a		720		728	780	719	660	425	475	
172	Filling-Emiss. [t]										
173	HFC-134a		22.5		24	31.5	37.5	42	37.2	17.4	
174	HFC-152a								9.30	21.6	
175	Subtotal Emiss. [t]		1823		1844	1592	1475	1362	897	894	
176	*Kilotonnes CO2 equiv.*		*1,534*		*1,553*	*1,164*	*1,084*	*1,005*	*662*	*587*	
177	**PU Hard+Integr. Foam**		1995		1998	1999	2000	2001	2002	2003	
178	First Year Emiss. [t]										
179	HFC-134a				92	92	92	92	92	97	
180	HFC-365mfc/245fa								20	21	
181	HFC-227ea								2	2	
182	Operating Emiss. [t]										
183	HFC-134a				0.49	1.48	2.47	3.46	4.45	5.43	
184	HFC-365mfc/245fa								0.28	0.89	
185	HFC-227ea								0.02	0.07	
186	Subtotal Emiss. [t]		0		92	93	94	95	118	126	
187	*Kilotonnes CO2 equiv.*		*0*		*120*	*121*	*123*	*124*	*148*	*158*	

	M	N	O	P	Q	R	S	T	U	V	W
128	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
129	2.6	4.4		2.6	4.4		2.6	4.4		2.6	4.4
130											
131											
132											
133	0.1	0.1		0.1	0.1		0.1	0.1		0.1	0.1
134	2.7	4.5		2.7	4.5		2.7	4.5		2.7	4.5
135	3.5	5.8		3.5	5.8		3.5	5.8		3.5	5.8
136	2010	2020		2010	2020		2010	2020		2010	2020
137	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
138	15	15		15	15		15	15		15	10
139	42	47		42	47		42	47		42	31
140	6	7		6	7		6	7		6	5
141											
142											
143											
144	3	3		3	3		2	2		2	2
145	7	9		7	9		5	6		5	6
146	1.0	1.3		1.0	1.3		0.7	0.9		0.7	0.9
147											
148											
149											
150	0.02	0.02		0.02	0.02		0.02	0.02		0.02	0.02
151	0.01	0.01		0.01	0.01		0.01	0.0113		0.01	0.01
152	0.00	0.00		0.00	0.00		0.00	0.00		0.00	0.00
153	75	81		75	81		71	77		71	54
154	*197.3*	*218.1*		*197.3*	*218.1*		*187.3*	*206.3*		*187.3*	*145*
155	2010	2020		2010	2020		2010	2020		2010	2020
156	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
157	44	48		44	48		44	48		44	24
158	6	8		6	8		6	8		6	4
159											
160	8	10		8	10		5	6.8		5	7
161		1.7			1.7			1.1			1.1
162	58.4	67.6		58.4	67.6		55.8	63.6		55.8	35.8
163	*88*	*107*		*88*	*107*		*85*	*101*		*85*	*57*
164	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
165	3,810	4,219		3,810	4,219		3,498	2,376		3,475	1,785
166	*5,065*	*5,616*		*5,065*	*5,616*		*4,627*	*2,765*		*4,624*	*2,405*
167											
168	2010	2020		2010	2020		2010	2020		2010	2020
169	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
170	1092	1092		449	449		22	22		0	0
171	728	728		560	560		28	28		0	0
172											
173	24	24		17.4	17.4		1	1		0	0
174				21.6	21.6		1	1		0	0
175	1844	1844		1048	1048		52	52		0	0
176	*1,553*	*1,553*		*688*	*688*		*34*	*34*		*0*	*0*
177	2010	2020		2010	2020		2010	2020		2010	2020
178	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
179	82	82		60	60		60	60			
180	435	435		268	268		268	268		157	28
181	33	33		20	20		20	20		6	1
182											
183	12	22		5.9	5.9		5.9	5.9		5.9	5.9
184	174	465		85	227		85	227		16	29
185	13	35		6	17		6	17		1	1
186	749	1072		446	598		446	598		186	65
187	*797*	*1133*		*477*	*634*		*477*	*634*		*181*	*64*

	A	B	C	D	E	F	G	H	I	J	L
188	**XPS Insulating Foam**		1995		1998	1999	2000	2001	2002	2003	
189	First Year Emiss. [t]										
190	HFC-134a							495	540	390	
191	HFC-152a							1150	1428	1313	
192	Operating Emiss. [t]										
193	HFC-134a							1.0	3.1	5.6	
194	HFC-152a										
195	Subtotal Emiss. [t]		0		0	0	0	1646	1971	1709	
196	*Kilotonnes CO2 equiv.*							*806*	*906*	*698*	
197	**Asthma MDIs**		1995		1998	1999	2000	2001	2002	2003	
198	Operating Emiss. [t]										
199	HFC-134a		0		27	36	47	106	160	171	
200	HFC-227		0		0	8	37	36	40	32	
201	Filling-Emiss. [t]										
202	HFC-134a							2	2	2	
203	HFC-227										
204	Subtotal Emiss. [t]		0		27	44	84	143	201	205	
205	*Kilotonnes CO2 equiv.*				*35*	*70*	*168*	*243*	*326*	*318*	
206	**Oth Aerosols/Solvents**		1995		1998	1999	2000	2001	2002	2003	
207	Operating Emiss. [t]										
208	HFC-134a (+43-10mee)		242		249	252	255	257	257	256	
209	HFC-152a		10		10	10	11	15	15	15	
210	Filling-Emiss. [t]										
211	HFC-134a		2.4		2.4	2.4	2.4	2.4	2.4	2.4	
212	HFC-152a		0.15		0.15	0.15	0.15	0.15	0.15	0.15	
213	Subtotal Emiss. [t]		254		262	264	269	274	274	274	
214	*Kilotonnes CO2 equiv.*		*318*		*329*	*331*	*336*	*339*	*339*	*339*	
215	**Fire Extinguishers**		1995		1998	1999	2000	2001	2002	2003	
216	Operating Emiss. [t]										
217	HFC-227				0.01	0.17	0.51	0.78	1.00	1.04	
218	HFC-236fa							0.00227	0.01453	0.031	
219	HFC-23										
220	Filling-Emiss. [t]										
221	HFC-227				0.002	0.004	0.080	0.067	0.033	0.020	
222	HFC-236fa							0.261	0.549	0.385	
223	HFC-23										
224	Disposal Emiss. [t]										
225	HFC-227										
226	HFC-236fa										
227	HFC-23										
228	Subtotal Emiss. [t]				0.01	0.18	0.6	1.11	1.6	1.5	
229	*Kilotonnes CO2 equiv.*				*0.04*	*0.5*	*1.7*	*4.1*	*6.5*	*5.7*	
230	**Semiconduct. HFC-23 [t]**		1995		1998	1999	2000	2001	2002	2003	
231	Emiss. [t]		1.06		1.00	1.05	1.44	1.22	0.94	1.33	
232	*Kilotonnes CO2 equiv.*		*12.4*		*11.7*	*12.3*	*16.9*	*14.3*	*11.0*	*15.6*	
233	**Magnesium Casting**		1995		1998	1999	2000	2001	2002	2003	
234	HFC-134a [t]									0.2	
235	*Kilotonnes CO2 equiv.*									*0.291*	
236											
241	**Subtot. HFC other use**										
242	Emiss. [t]		2,077		2,226	1,994	1,924	3,523	3,464	3,211	
243	*Kilotonnes CO2 equiv.*		*1,865*		*2,048*	*1,700*	*1,729*	*2,535*	*2,398*	*2,121*	
244											
245	**Total HFC-Use**		1995		1998	1999	2000	2001	2002	2003	
246	Total HFC-Use Emiss [t]										
247	Subtotal I stat [t]		73		516	696	854	1,004	1,155	1,339	
248	Subtotal II mobil [t]		170		677	921	1,168	1,409	1,653	1,908	
249	Subtotal III other [t]		2,077		2,226	1,994	1,924	3,523	3,464	3,211	
250	Subtotal HFC Use Ems. [t]		2,319		3,419	3,611	3,946	5,936	6,273	6,459	
251											

	M	N	O	P	Q	R	S	T	U	V	W
188	2010	2020		2010	2020		2010	2020		2010	2020
189	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
190	765	932		586	714		630	769		126	0
191	2868	3496		1673	2040		335	0		335	0
192											
193	32.5	74.3		24.5	56.6		25.6	60.2		20	23
194											
195	3666	4503		2283	2810		991	829		480	23
196	*1,438*	*1,798*		*1,028*	*1,287*		*900*	*1,077*		*236*	*30*
197	2010	2020		2010	2020		2010	2020		2010	2020
198	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
199	352	474		234	314		234	314		192	146
200	88	118		49	66		49	66		40	31
201											
202	3	3		3	3		3	3		2	2
203				1	1		1	1		1	0
204	443	595		286	384		286	384		235	179
205	*717*	*963*		*451*	*607*		*451*	*607*		*370*	*283*
206	2010	2020		2010	2020		2010	2020		2010	2020
207	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
208	257	257		257	257		162	162		2	2
209	15	15		15	15		10	10		0	0
210											
211	2.4	2.4		2.4	2.4		0.00	0.00		0	0
212	0.15	0.15		0.15	0.15		0.00	0.00		0	0
213	275	275		275	275		172	172		2	2
214	*339*	*339*		*339*	*339*		*212*	*212*		*3*	*3*
215	2010	2020		2010	2020		2010	2020		2010	2020
216	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
217	5.3	7.5		5.3	7.5		5.3	7.5		5.3	7.5
218	0.6	0.6		0.6	0.6		0.6	0.6		0.6	0.6
219	0.35	1.84		0.35	1.84		0.35	1.84			
220											
221	0.050	0.050		0.050	0.050		0.050	0.050		0.050	0.050
222	0.384	0.386		0.384	0.386		0.384	0.386		0.384	0.386
223	0.01	0.01		0.01	0.01		0.01	0.01			
224											
225		1.0			1.0			1.0			1.0
226		0.075			0.075			0.075			0.075
227		0.050			0.050			0.050			
228	6.7	11.5		6.7	11.5		6.7	11.5		6.3	9.6
229	*25.9*	*53.7*		*25.9*	*53.7*		*25.9*	*53.7*		*21.7*	*31*
230	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
231	3.6	9.4		1.0	1.0		1.0	1.0		1.0	1.0
232	*42.6*	*110.5*		*11.1*	*11.1*		*11.1*	*11.1*		*11.1*	*11.1*
233	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With Measures	
234	0	0		0.2	0.2		10.9	17.3		12.4	19.9
235	*0.0*	*0.0*		*0.3*	*0.3*		*14.2*	*22.5*		*16.1*	*25.9*
236											
241	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
242	6,986	8,310		4,346	5,128		1,966	2,065		922	279
243	*4,913*	*5,951*		*3,021*	*3,621*		*2,126*	*2,652*		*838*	*449*
244											
245	2010	2020		2010	2020		2010	2020		2010	2020
246	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
247	2,255	2,496		2,128	2,368		1,511	1,567		1,501	1,194
248	3,810	4,219		3,810	4,219		3,498	2,376		3,475	1,785
249	6,986	8,310		4,346	5,128		1,966	2,065		922	279
250	13,051	15,024		10,283	11,715		6,974	6,008		5,899	3,258
251											

	A	B	C	D	E	F	G	H	I	J	L
252	Total HFC Use Ems.										
253	Subtotal Stat Use		169		1,170	1,599	1,994	2,375	2,758	3,205	
254	Subtotal Mobile Use		234		915	1,241	1,571	1,892	2,218	2,567	
255	Subtotal Other use		1,865		2,048	1,700	1,729	2,535	2,398	2,121	
256	*Kilotonnes CO2 equiv.*		*2,267*		*4,133*	*4,540*	*5,294*	*6,802*	*7,374*	*7,894*	
257											
258	**HFC Production etc.**		1995		1998	1999	2000	2001	2002	2003	
263	Total HFC Prod. Ems. [t]		360		259	248	128	119	132	74	
264	*Kilotonnes CO2 equiv.*		*4,212*		*2,833*	*2,673*	*1,207*	*1,091*	*1,212*	*533*	
265											
266	**Total HFC Emiss. [t]**		2,679		3,678	3,858	4,073	6,054	6,404	6,532	
267	*Kilotonnes CO2 equiv.*		*6,479*		*6,966*	*7,213*	*6,501*	*7,893*	*8,586*	*8,427*	
268											
269	**PFC**		1995		1998	1999	2000	2001	2002	2003	
270	**Aluminium Production**										
271	Manuf. Emiss. [t]										
272	CF4		209		157	116	48	50	58	64	
273	C2F6		21		15.7	12	5	5	5.8	6.6	
274	Emiss PFC [t]		230		173	128	53	55	64	70	
275	*Kilotonnes CO2 equiv.*		*1,552*		*1,166*	*864*	*356*	*372*	*431*	*475*	
276	**Refrigerants**		1995		1998	1999	2000	2001	2002	2003	
277	Oper. + Disp. Emiss. [t]										
278	C2F6 (R-116)				0.5	0.8	1.2	1.7	2.1	2.5	
279	C3F8 (R-218)		1.2		7.3	9.4	10.3	11.1	11.7	12.1	
280	Emiss PFC [t]		1.2		7.8	10.2	11.6	12.7	13.7	14.7	
281	*Kilotonnes CO2 equiv.*		*8.1*		*55.7*	*73.2*	*83.8*	*92.7*	*101*	*108*	
282	**PCB Manufacture**		1995		1998	1999	2000	2001	2002	2003	
283	Manuf. Emiss. [t]										
284	CF4		2		2	2	2	2	2	2	
285	Emiss PFC [t]		2		2	2	2	2	2	2	
286	*Kilotonnes CO2 equiv.*		*13*		*13*	*13*	*13*	*13*	*13*	*13*	
287	**Semiconductors**		1995		1998	1999	2000	2001	2002	2003	
288	Manuf. Emiss. [t]										
289	C2F6		11.3		17.3	18.8	18.5	12.7	12.8	14.4	
290	CF4		11.2		11.7	17.1	20.5	15.8	15.5	14.3	
291	C3F8		0		0.2	0.8	4.1	3.7	4.3	4.8	
292	c-C4F8		0		0.1	0.2	0.1	0.1	0.1	0.2	
293	Emiss PFC [t]		23		29	37	43	32	33	34	
294	*Kilotonnes CO2 equiv.*		*177*		*238*	*292*	*333*	*246*	*250*	*260*	
295											
296	**Total PFCs**		1995		1998	1999	2000	2001	2002	2003	
297	PFC Emiss [t]		256		212	177	110	102	112	121	
298	*Kilotonnes CO2 equiv.*		*1,750*		*1,473*	*1,243*	*786*	*723*	*795*	*856*	
299											
300	**SF6**		1995		1998	1999	2000	2001	2002	2003	
301	**El. Eqipment T&D**										
302	Manufact. Switchgear t		20.0		16.6	10.8	9.5	7.3	8.0	5.44	
303	Manufact. Components t		16.0		14.0	14.0	13.2	14.5	14.4	12.40	
304	Bank Emissions t		7.3		8.1	8.5	7.7	8.0	8.2	8.42	
305	Disposal Emissions t				0.06	0.06	0.06	0.06	0.06	0.06	
306	Subtotal Emiss. [t]		43.4		38.7	33.4	30.4	29.8	30.7	26.3	
307	*Kilotonnes CO2 equiv.*		*1,036*		*924*	*798*	*727*	*713*	*733*	*629*	
308											
309	**Other Electr. Applic.**		1995		1998	1999	2000	2001	2002	2003	
310	Manuf. Emissions t		0.7		12.0	11.6	13.5	12.6	8.9	6.0	
311	Bank Emissions t		4.4		4.9	4.8	5.0	4.8	4.9	4.9	
312	Disposal Emissions t		0.07		0.04	0.09	0	0	0	0	
313	Subtotal Emiss. [t]		5.2		17.0	16.6	18.4	17.4	13.8	10.9	
314	*Kilotonnes CO2 equiv.*		*125*		*405*	*396*	*441*	*416*	*329*	*260*	

	M	N	O	P	Q	R	S	T	U	V	W
252	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
253	5,684	6,062		5,288	5,666		3,704	3,683		3,681	2,748
254	5,065	5,616		5,065	5,616		4,627	2,765		4,624	2,405
255	4,913	5,951		3,021	3,621		2,126	2,652		838	449
256	*15,662*	*17,629*		*13,374*	*14,903*		*10,458*	*9,100*		*9,143*	*5,602*
257	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
258	2010	2020		2010	2020		2010	2020		2010	2020
263	272	272		74	74		74	68		52	46
264	*2,851*	*2,851*		*535*	*535*		*535*	*527*		276	268
265											
266	13,323	15,296		10,357	11,789		7,048	6,076		5,950	3,303
267	*18,513*	*20,480*		*13,908*	*15,437*		*10,992*	*9,626*		9,419	5,869
268											
269	2010	2020		2010	2020		2010	2020		2010	2020
270	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
271											
272	128.5	128.5		55	55		55	55		44	44
273	12.8	12.8		5	5		5	5		4	4
274	141.3	141		60	60		60	60		48	48
275	*953*	*953*		*408*	*408*		*408*	*408*		*325*	*325*
276	2010	2020		2010	2020		2010	2020		2010	2020
277	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
278	5.6	5.6		5.6	5.6		3.6	3.3		3.6	2.4
279	3.0			3.0			3.0			3.0	
280	8.5	5.6		8.5	5.6		6.6	3.3		6.6	2.4
281	*71.9*	*51.1*		*71.9*	*51.1*		*54.2*	*29.9*		*54.0*	*21.9*
282	2010	2020		2010	2020		2010	2020		2010	2020
283	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
284	2	2		2	2		2	2		2	2
285	2	2		2	2		2	2		2	2
286	*13*	*13*		*13*	*13*		*13*	*13*		*13*	*13*
287	2010	2020		2010	2020		2010	2020		2010	2020
288	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
289	47.0	122.0		10.2	10.2		10.2	10.2		10.2	10.2
290	38.0	98.7		10.1	10.1		10.1	10.1		10.1	10.1
291	0.2	0.5		0.0	0.0		0.0	0.0		0.0	0.0
292	0.1	0.2		0.0	0.0		0.0	0.0		0.0	0.0
293	85	221		20	20		20	20		20	20
294	*682*	*1769*		*159*	*159*		*159*	*159*		*159*	*159*
295	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
296	2010	2020		2010	2020		2010	2020		2010	2020
297	237	370		91	88		89	86		77	73
298	*1,720*	*2,786*		*652*	*631*		*634*	*610*		*551*	*519*
299											
300	2010	2020		2010	2020		2010	2020		2010	2020
301	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
302	22.5	22.7		6.9	7.0		6.9	7.0		6.8	6.9
303	14.0	14.0		12.4	12.4		12.4	12.4		6.5	1.5
304	10.5	10.1		9.9	9.6		9.9	9.6		8.7	7.3
305	0.5	0.9		0.5	0.9		0.5	0.9		0.50	0.9
306	47.5	47.7		29.7	30.0		29.7	30.0		22.5	16.6
307	*1,135*	*1,140*		*711*	*716*		*711*	*716*		*537*	*398*
308											
309	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
310	12.02	12.02		1.02	1.02		1.02	1.02		0.02	0.02
311	4.9	4.9		4.9	4.9		4.9	4.9		4.9	4.9
312	0.04	0.04		0.04	0.04		0.04	0.04		0.04	0.04
313	17.0	17.0		6.0	6.0		6.0	6.0		5.0	5.0
314	*405*	*405*		*142*	*142*		*142*	*142*		*118*	*118*

	A	B	C	D	E	F	G	H	I	J	L
315											
316	**Magnesium Casting**		1995		1998	1999	2000	2001	2002	2003	
317	Manufacturing Emiss t		7.7		9.2	8.6	13.2	17.3	16.0	19.1	
318	Subtotal Emiss. [t]		7.7		9.2	8.6	13.2	17.3	16.0	19.1	
319	*Kilotonnes CO2 equiv.*		*185*		*220*	*206*	*316*	*413*	*383*	*457*	
320											
321	**Soundproof Glazing**		1995		1998	1999	2000	2001	2002	2003	
322	Mauf. Emissions t		92		37	32	28.6	25	14	10	
323	Bank Emissions t		16		20	20	20.4	21	21	21	
324	Disposal Emissions t						2.7	6	11	18	
325	Subtotal Emiss. [t]		107.9		56.5	52	51.7	51	46.4	48.3	
326	*Kilotonnes CO2 equiv.*		*2,578*		*1,350*	*1,244*	*1,236*	*1,227*	*1,108*	*1,155*	
327											
328	**Car Tires**		1995		1998	1999	2000	2001	2002	2003	
329	Disposal Emissions t		110		125	67	50	30	9	6	
330	Subtotal Emiss. [t]		110.0		125.0	67	50	30	9	6	
331	*Kilotonnes CO2 equiv.*		*2,629*		*2,988*	*1,601*	*1,195*	*717*	*215*	*143*	
332											
333	**Soles/Radar/Gl. Fibre**		1995		1998	1999	2000	2001	2002	2003	
334	Subtotal Emiss. [t]		18.5		22.3	24	23.3	15	16.6	15.4	
335	*Kilotonnes CO2 equiv.*		*442*		*532*	*574*	*557*	*365*	*396*	*369*	
336											
337	**Tracergas/Al-Cleaning**		1995		1998	1999	2000	2001	2002	2003	
338	Manufacturing Emiss t		1.0		1.0	11.0	14.5	32.5	35.5	45.5	
339	Subtotal Emiss. [t]		1.0		1.0	11.0	14.5	32.5	35.5	45.5	
340	*Kilotonnes CO2 equiv.*		*23.9*		*23.9*	*263*	*347*	*777*	*848*	*1,087*	
341											
342	**Semiconductors**		1995		1998	1999	2000	2001	2002	2003	
343	Manufacturing Emiss t		2.0		2.4	2.2	2.4	1.8	2.4	2.6	
344	Subtotal Emiss. [t]		2		2	2	2	2	2	2.6	
345	*Kilotonnes CO2 equiv.*		*49*		*58*	*52*	*56*	*44*	*56*	*62*	
346	23900										
347	**Other SF6**		1995		1998	1999	2000	2001	2002	2003	
348	SF6		7		9	8	9	10	10	10	
349	Subtotal Emiss. [t]		7		9	8	9	10	10	10	
350	*Kilotonnes CO2 equiv.*		167		215	191	215	239	239	239	
351											
352			1995		1998	1999	2000	2001	2002	2003	
353	**Total SF6**										
354	Total Emiss. [t]		303		281	223	213	205	180	184	
355	*Kilotonnes CO2 equiv.*		*7,235*		*6,716*	*5,325*	*5,090*	*4,910*	*4,308*	*4,402*	
356											
357											
358	**Total F-Gas-Emissions**		1995		1998	1999	2000	2001	2002	2003	
359											
360	Total HFC [t]		2,679		3,678	3,858	4,073	6,054	6,404	6,532	
361	Total PFC [t]		256		212	177	110	102	112	121	
362	Total SF6 [t]		303		281	223	213	205	180	184	
363	Total F-Gas Emiss. [t]		3,237		4,171	4,258	4,396	6,362	6,697	6,837	
364											
365	HFC ktonnes CO2 eqiv.		6,479		6,966	7,213	6,501	7,893	8,586	8,427	
366	PFC ktonnes CO2 eqiv.		1,750		1,473	1,243	786	723	795	856	
367	SF6 ktonnes CO2 eqiv.		7,235		6,716	5,325	5,090	4,910	4,308	4,402	
368	*Kilotonnes CO2 equiv.*		15,464		15,156	13,781	12,376	13,526	13,689	13,685	

	M	N	O	P	Q	R	S	T	U	V	W
315											
316	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
317	41	71		33,1	53,1		4,0	7,0		0,0	0,0
318	40,9	70,8		33,1	53,1		4,0	7,0		0,0	0,0
319	*977*	*1692*		*791*	*1269*		*96*	*167*		*0,0*	*0,0*
320											
321	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
322	37	37		10	10		0	0		0	0
323	23	19		18	9		17	6,6		17	6,6
324	67	143		67	143		67	143		67	143
325	127,0	198,5		95,3	162,0		84,3	149,1		84,3	149,1
326	*3.036*	*4.745*		*2.279*	*3.872*		*2.015*	*3.564*		*2.015*	*3.564*
327											
328	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
329	30	30		2,5	2,5		0,0	0,0		0,0	0,0
330	30,0	30,0		2,5	2,5		0,0	0,0		0,0	0,0
331	*717*	*717*		*60*	*60*		*0,0*	*0,0*		*0,0*	*0,0*
332											
333	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
334	10	10		10	10		10	10		10	10
335	*239*	*239*		*239*	*239*		*239*	*239*		*239*	*239*
336											
337	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
338	40,5	40,5		40,5	40,5		40,5	40,5		0,5	0,5
339	40,5	40,5		40,5	40,5		40,5	40,5		0,5	0,5
340	*968*	*968*		*968*	*968*		*968*	*968*		*12*	*12*
341											
342	w/o Measures as of 99			With Measures until 2003			EU Legislation 2007			With further Measures	
343	6,6	17,2		0,4	0,4		0,4	0,4		0,4	0,4
344	7	17		0,4	0,4		0,4	0,4		0,4	0,4
345	*158*	*411*		*9*	*9*		*9*	*9*		*9*	*9*
346											
347	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
348	10	10		10	10		10	10		10	10
349	10	10		10	10		10	10		10	10
350	239	239		239	239		239	239		239	239
351											
352	2010	2020		2010	2020		2010	2020		2010	2020
353	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
354	329	442		228	314		185	253		133	192
355	*7.875*	*10.556*		*5.438*	*7.514*		*4.418*	*6.045*		*3.169*	*4.579*
356											
357											
358	2010	2020		2010	2020		2010	2020		2010	2020
359	w/o Measures from 99			With Measures until 2003			EU Legislation 2007			With further Measures	
360	13.323	15.296		10.357	11.789		7.048	6.076		5.950	3.303
361	237	370		91	88		89	86		77	73
362	329	442		228	314		185	253		133	192
363	13.890	16.108		10.676	12.192		7.322	6.415		6.160	3.568
364											
365	18.513	20.480		13.908	15.437		10.992	9.626		9.419	5.869
366	1.720	2.786		652	631		634	610		551	519
367	7.875	10.556		5.438	7.514		4.418	6.045		3.169	4.579
368	28.108	33.822		19.998	23.582		16.045	16.281		13.139	10.967

Part III

Historic 1990 Emission Data

Introduction

In this third part, emission data on fluorinated greenhouse gases are estimated and documented for the reporting year 1990. It is true that for these gases reference year for emission reduction measures according to Kyoto Protocol is 1995. Emission reporting, however, follows UNFCCC; therefore, basic year for reporting is the same as for the Framework Convention on Climate Change itself, namely 1990. Although 1990 emission data are of particular importance, they have been neglected in Germany, so far.

The following estimates of activity data and emissions will compensate for this deficiency. To make easier transfer into existing reporting formats and into ZSE (Centralised Systems Emissions), individual emission sources are presented right in CRF tables in the order of the three (key) sources 2.C (Metal Production), 2.E (Production of Halocarbons), and 2.F (Consumption of F-Gases). This breakdown is not the same as the division into three substance groups PFCs, HFCs, and SF_6. The latter is applied in the third chapter of this part III where the climate impact of the 1990 emissions is recapitulated.

The peculiarity of the 1990 emission picture becomes promptly apparent even from the emission sources' perspective: Of decisive importance are the substances SF_6 and PFCs (CF_4 and C_2F_6), while specifically applied HFCs, currently by far the largest fluid group, do not yet occur except for the small use as semiconductor etching gas. Nevertheless, "old" unwanted HFCs (by-product emissions from HCFC-22-production) show high global warming impact.

The first German UBA study on emissions of fluorinated greenhouse gases from 1996 (Schwarz/Leisewitz) was thoroughly striving towards comparison figures from 1990. Subsequently, some of them are presented unaltered. In other cases, the improved scrutiny acquired over the recent nine years of data collection made retroactive corrections possible and necessary. For example, the 1990 emission data from source 2.E "Production of Halocarbons" is now completely new. Subsequent to the 1990 activity data and emissions presented in CRF Tables, for each single emission source references are given.

Data documentation is limited to these mostly short references to avoid repetition of information cited elsewhere. Those, who miss discussions on the methods applied, are referred to the now and then aforementioned study "Emissions, Activity Data, and Emission Factors of Fluorinated Greenhouse Gases (F-Gases) in Germany 1995-2002", released in 2005 as UBA-Text 15/05. There, for each individual emission sector not only descriptions of the sector itself and of the methods of data collection applied can be found, but also reasons for emission factors and assessments of the data quality, accuracy and certainty. What is said about 1995-2002, is often applicable to 1990 with just little reservations. This study is cited "UBA-Text 15/05". It provides the possibility for further information, together with the study "Current and future emissions of fluorinated compounds with global warming impact in Germany" from December 1996 (cited: Schwarz/Leisewitz 1996, available in German language only).

First Chapter.
Source Groups 2.C and 2.E in 1990

In the following, basic understanding of the CRF tables is presupposed.

Table 16

TABLE 2(II). C, E SECTORAL BACKGROUND DATA FOR INDUSTRIAL PROCESSES					Germany
Metal Production; Production of Halocarbons and SF_6					1990
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	**ACTIVITY DATA**		**IMPLIED EMISSION FACTORS**	**EMISSIONS**	
	Description	**(t)**	**(kg/t)**	**(t)**	**(t)**
C. PFCs and SF_6 from Metal Production					
PFCs from Aluminium Production					
CF_4	Al-production	740.300	0.453	335.5	
C_2F_6	Al-production	740.300	0.045	33.5	
SF_6				7.9	
Aluminium Foundries	*(SF_6 consumption)*	0.50	NA	0.5	
Magnesium Foundries	Mg-production	2.000	3.70	7.4	
E. Production of Halocarbons and SF_6					
1. By-product Emissions					
Production of HCFC-22	Production	31.400			
HFC-23			11.78	370	[360]
Production of CFC-11/12	Production	72.000			
PFC-14 (CF4)			0.17	12	[5]
2. Fugitive Emissions					
HFCs *(specify chemical)*					
SF_6	Production	Confid.	Confid.	5	

The figure [360] in squared brackets in the last column to the right means HFC-23 (in tonnes), as far as it was captured and processed to refrigerants or Halons; the [5] means CF_4, captured and distilled to etching gas. Both measures reduce immediate plant emissions.

References

PFC emissions from aluminium production (CF_4, C_2F_6)

Production and emission data documented since 1995 refer to five domestic smelters. In 1990, however, there were another five smelters in operation. Two of them were situated in the GDR, and were closed in the same year. Three were run in the old West German states and were closed in the beginning nineties.

In 1996, all 1990 data had been collected or estimated with reasonable care, and were presented and documented in Schwarz/Leisewitz 1996, p. 61-72.

SF$_6$ application in aluminium foundries (cleaning agent for molten metal)

Consumption and – equal – emissions stem likewise from Schwarz/Leisewitz 1996, p. 50 (unaltered).

SF$_6$ application in magnesium die casting (cover gas)

Consumption and – equal - emissions: Schwarz/Leisewitz 1996, p. 39-44 (controlled and confirmed 2005).

By-product emissions of HFC-23 from HCFC-22 manufacture

Unwanted 1990 HFC-23 emissions were estimated at 200 t in Schwarz/Leisewitz 1996, p. 125/126. In addition, a captured fraction of 10 t was indicated, which was partly sold as low-temperature refrigerant R-23 and partly processed to bromine-containing refrigerant R-13B1.

These estimates were exclusively based on the largest of the three then running HCFC-22 plants in Germany (including GDR), namely the Frankfurt am Main plant of Hoechst AG.

In 2005, the current operators of the second largest German plant (Bad Wimpfen) in 1990 were interviewed again. They confirmed their statement given to Öko-Recherche on 23 April 1996 that in 1990 all arising HFC-23 had been captured and used as raw material for Halon 1301 so that emissions worth mentioning did not occur.

In 2005, retroactively also HCFC-22 production in the 1990 GDR (third plant) was tracked. Pursuant to Mr Rainer Niepel (03.06.2005), today managing director of HF-producing Fluorchemie Dohna GmbH, on a pilot plant in Dohna (near Dresden) HCFC-22 had been produced until 1991 with an annual output of roughly 1,100 t. Inevitably arising HFC-23 was discharged to the atmosphere without further treatment. Since no measurements had been carried out, in order to estimate the 1990 emissions the international default emission factor of 3% (in relation to HCFC-22 output) is applied. Correspondingly, from this plant some 30 t HFC-23 emitted which had not been considered up to now in 1990 emissions assessment.

Finally, the 1990 data on the Hoechst plant were reviewed. In Öko-Recherche archives a fax from Hoechst AG (Mr Schönfeld, Mr Harder) dated 14.08.1991 was found, which figured the 1990 production of HCFC-22 at 20,842 t. In this context the statement of the Hoechst experts (Dr. Hug, Dr. Debrodt) from 23.03.1996 to Schwarz/Leisewitz that "the share of R-23 is between 1.5 and 2% of R-22", was seriously doubted and considered too small. Instead, we assume the inevitable 1990 HFC-23 generation at the Hoechst plant in the range between 300 and 400 t (instead of just 200 t). Here, it is estimated at 350 t. Thereof 10 t have to be subtracted for refrigerant use (23, 13B1). Thus, 340 t emitted to the atmosphere, by our count.

It should be mentioned here, that since 1995 in Frankfurt all surplus HFC-23 is piped directly to an adjacent thermal cracking reactor for complete destruction.

By-product emissions of CF_4 (R-14) from CFC production

In Schwarz/Leisewitz 1996, p. 75, the 1990 quantity of CF_4 or PFC-14 (R-14) inevitably arising from the synthesis of CFC-11/CFC-12 was figured 15 t. Thereof 5 t were captured and after distilling purification sold to semiconductor and electronics industry as etching gas. Thus, CF_4 emissions amounted to 10 t. In April 1994, CFC production ceased, and production of HFC-134a started.

As with HFC-23, the 1990 data exclusively come from the largest German CFC plant which was likewise run by the Hoechst AG in Frankfurt.

In 2005, the operators of the 1990 second largest CFC plant were asked for a check up of their statement to Öko-Recherche from 23.04.1996 that their CFC production was not associated with CF_4 emissions. Answer: "The main focus of CFC production at Solvay Fluor in Bad Wimpfen plant was CFC-11 for foam applications. Therefore, fluorination of CTC (CCl_4) was operated in a way that minimised the CFC-12 by-product, thus leading to only small amounts of CFC-13, and virtually no CFC-14. In fact, according to my colleagues PFC-14 was never detected in the final raw product. PFC-14 emissions from the Wimpfen plant can be equated with zero." (Dr. Ewald Preisegger, Solvay Fluor & Derivate GmbH, 27.06.2005).

In 2005, retroactively also R-14 emissions in the 1990 GDR were tracked down. In Nünchritz near Dresden, a site of "VEB Chemiekombinat Bitterfeld", CFC-11 and CFC-12 were produced. Production ceased in 1992 after West German Hüls AG had purchased the "Chemiewerk Nünchritz" for their silicone industry. (Archive data Öko-Recherche). The then CFC capacity was 10,000 to 11,000 t (Robin Wood Magazin, Nr. 29/2.1991, p. 27). In 1990, actual production was 7,000 t, by our count.

Applying the same relation between R-14 generation and CFC-11/12 output as in Hoechst, namely 0.03%, R-14 emissions from Nünchritz can be estimated at some 2 t in 1990.

For information only, the 1990 summed-up production of CFC-11/-12 by Hoechst AG in Frankfurt and by Kali-Chemie (later-on Solvay) in Wimpfen should be mentioned. Hoechst: 42,500 t (Fax Hoechst AG, 14.08.1991, Mr Harder, Mr Schönfeld); Kali-Chemie: 22,500 t.

Emissions from SF_6 production

In 1990, in whole Germany SF_6 was produced only in Bad Wimpfen. As yet, neither output nor associated fugitive emissions have been investigated. The today operator, Solvay Fluor GmbH, retroactively established the 1990 production figure which is confidential in the public version of this study (Ewald Preisegger, Solvay Fluor & Derivate GmbH, Hannover, 27.06.2005). Emissions are estimated by Öko-Recherche at 5 t.

Second Chapter.
Source Group 2.F in 1990

Table 17

TABLE 2(II).F SECTORAL BACKGROUND DATA FOR INDUSTRIAL PROCESSES							Germany		
Consumption of Halocarbons and SF_6							1990		
	ACTIVITY DATA			**IMPLIED EMISSION FACTORS**			**EMISSIONS**		
	Amount of fluid			**Product manu-facturing factor**	**Product life factor**	**Disposal loss factor**	**From manu-facturing**	**From stocks**	**From dis-posal**
	Filled in new manu-factured products	**In operating systems (average annual stocks)**	**Re-mained in products at decomm-issioning**						
	(t)			**(% per annum)**			**(t)**		
SF_6 Applications									
Electricity T&D equipm.	273	800		*10%*	*1%*		30.0	8.0	
Soundproof glazing	180	903		*33%*	*1%*		59.4	9.0	
Car Tires	100	250	65			*100%*			65.0
Tracer Gas	0.5			*100%*			0.5		
Shoe Soles/Radar									7.0
Particle Accelerators	2	65		*1%*	*8%*		0.02	5.2	
Semiconductors/Electronics									
Semiconductors CF_4	8			*85%*			6.8		
Semiconductors C_2F_6	12			*75%*			8.4		
Semiconductors CHF_3	4			*85%*			3.4		
Semiconductors NF_3	1			*40%*			0.4		
Semiconductors SF_6	5			*73%*			3.7		
Electronics CF_4	3			*85%*			2.6		

NF_3 is only mentioned in the Table. It is not yet considered by CRF as global warming gas.

References

<u>Equipment for transmission and distribution of electricity</u>
Bank and bank emissions: Schwarz/Leisewitz 1996, p. 14-24, reviewed and confirmed 2005.
Consumption and manufacturing emissions newly reconstructed in 2005 by means of data from annual ZVEI-VDN-Monitoring in the frame of the 1997 self-commitment, as well as with the personal help of experts like Friedrich Plöger (Siemens AG), Jürgen Voss (Ritz Messwandler GmbH & Co. KG), Johannes Stein (ZVEI, Section Switchgear, Control gear, Industrial Control Equipment).

<u>Soundproof glazing</u>
Consumption, bank, and emissions: Schwarz/Leisewitz 1996, p. 25-32. Revised 2004 in: UBA-Text 15/05, p. 214-226.

Car tires
Consumption and emissions: Schwarz/Leisewitz 1996, p. 34-38, corrected in the course of the study on activity data and emission factors, UBA-Text 15/05, p. 227-231.

Tracer gas
Consumption and emissions: Schwarz/Leisewitz 1996, p. 49 (unaltered).

Aircraft radar
Emissions newly established in UBA-Text 15/05, p. 243-246 (Data confidential).

Sport shoe soles
Emissions established in the frame of the study Schwarz/Leisewitz 1996 (Data source is published there, data itself is confidential).

Particle accelertors
Consumption, bank, and emissions first in Schwarz/Leisewitz 1996, p. 45/46. Reconstructed in the frame of the Öko-Recherche Survey 2004 (not published as a whole, but in its main results integrated in UBA-Text 15/05, p. 252-258).

Semiconductor industry: SF_6, CF_4, C_2F_6, CHF_3, NF_3
Consumption and emissions: Schwarz/Leisewitz 1996, p. 133-142 (controlled and confirmed 2005).

Electronics industry (Cleaning of printed circuit boards with CF_4)
Consumption and emissions: Schwarz/Leisewitz 1996, p. 74 (controlled and confirmed 2005).

Third Chapter.
Ecological Assessment of 1990 Emissions

In Tables 16 and 17, the individual emission sectors are attributed to source-groups. When subsuming the sectors under substance-groups, following picture emerges.

Table 18: 1990 Emissions by Substance Groups

Substance Group	Emissions in metric t	Emissions in kt CO_2 equivalent	*Average GWP*
PFC (CF_4, C_2F_6)	399	2,705	*6,784*
HFC-23 (CHF_3)	373	4,369	*11,700*
SF_6	201	4,797	*23,900*
Total	973	11,871	*12,202*

Sources: Table 16 and Table 17.

Overall 1990 F-gas emissions amounted to only 973 metric tonnes. This is a small fraction of 2003 emissions of 6,848 tonnes (see part II, first chapter). However, with respect to global warming 1990 emissions are 11.87 million t CO_2 equivalent, which is not much below the 2003 value of 13.71 million t. This is because in 1990 only F-gases with extremely high GWP were emitting, namely CF_4 (GWP: 6,500), C_2F_6 (9,200), CHF_3 (11,700), and SF_6 (23,900). Average GWP (see Table 18, last column, last row) figured 12,202 (1990) versus calculated 2,000 in 2003.

The intentionally as CFC successors applied new HFCs like HFC-134a have a GWP of "only" 1300 or generally between 140 und 3300. Therefore, the steep rise in F-gas emissions from 1990 onwards that results from increased use of HFCs is reflected in only moderate growth of global warming contribution.

In addition to that, emissions of "old" F-gases from the time before CFC substitution tend to decrease from 1990 onwards.

- The overall PFC (above all CF_4) emissions of 400 t in 1990 have been reduced – primarily owing to modernisation efforts in aluminium industry – to 121 t in 2003.

- Even sharper is the drop in emissions of HFC-23 from production of HCFC-22. Here, chemical industry has achieved sustained success.

- All the more striking is the relative constancy of SF_6 emissions. They have only decreased from 201 t (1990) to 184 t (2003), after a transitory peak of more than 300 t in 1995. Since a sharp rise in emissions from the single source soundproof glazing is certain until 2020, political measures (EC Regulation on F-Gases) to reduce emissions seem to be appropriate particularly in this area.

Today, the possible emission reduction potential of "old" F-gases is already tapped largely. If reduction of global warming F-gas emissions below the 1990 level is a political goal, further measures are necessary to mitigate emissions of "new" F-gases that have been manufactured specifically for use. No doubt, EC Directive on HFC-134a phase-out in mobile air conditioners is an important step in this direction.

Annex: GWP values used in this study

GWP values of the fluorinated compounds treated in the study (excluding chlorinated substances)			
Substance	Empirical formula or composition	Name	GWP 100
Perfluorocarbons (PFC)			
	CF_4	14	6500
	C_2F_6	116	9200
	C_3F_8	218	7000
	c-C_4F_8	318	8700
Hydrofluorocarbons (HFC)			
	CHF_3	23	11700
	CH_2F_2	32	650
	C_2HF_5	125	2800
	$C_2H_2F_4$	134a	1300
	$C_2H_3F_3$	143a	3800
	$C_2H_4F_2$	152a	140
	C_3HF_7	227ea	2900
	$C_3H_2F_6$	236fa	6300
	$C_3H_3F_5$	245fa	950*
	$C_4H_5F_5$	365mfc	890*
	$C_5H_2F_{10}$	43-10mee	1300
Blended Refrigerants (without "Drop-In"-mixtures)			
	143a/125/134a (52/44/4)	404A	3260
	32/125/134a (23/25/52)	407C	1525.5
	32/125 (50/50)	410A	1725
	125/143a (50/50)	507	3300
	116/23 (54/46)	508B	10350
Others			
	SF_6		23900

Explanation

The GWP values are taken from the Second Assessment Report (SAR) of the IPCC from 1996, which are still valid for UNFCCC reporting. Only for HFC-365mfc and -245fa the Third Assessment Report (TAR) of the IPCC from 2001 is applied, because the two substances do not yet occur in IPCC SAR 1996.

Literature

IPCC (1996) *Climate Change 1995: The Science of Climate Change*. Intergovernmental Panel on Climate Change; J.T. Houghton, L.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg, and K. Maskell, eds.; Cambridge University Press. Cambridge, U.K.

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