Emissions Reduction Potentials for SF_6 in Germany

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Abstract

In Germany, five relevant emission sources of SF_6 were identified. Total emissions of SF_6 from these sources dropped from 260 t to 229 t between 1995 and 1998. In a business-as-usual scenario, which assumes the absence of additional measures, the SF_6 emissions were forecast to fall to 210 t/a by the year 2010. Potential for a further reduction of 86 t/a was identified in a second scenario, which assumed the implementation of additional ecologically and economically reasonable, technically feasible measures.

SF_6 emissions from electrical equipment remained more or less unchanged, while emissions from magnesium casting decreased by half between 1995 and 1998. This trend is expected to continue until the year 2010. The application of a recycling concept is expected to bring about a considerable additional reduction, about 40 t/a, in emissions of SF_6 from electrical equipment after 2010. In this paper, a system for monitoring SF_6 emissions from electrical equipment is presented, as are the main results of the business-as-usual scenario and the reduction scenario and the most important of the underlying measures.

1 Introduction

In 1996 and 1999 the German Federal Environmental Agency (UBA) commissioned the German Öko-Recherche institute to assess emissions of HFCs, PFCs, and SF_6 in Germany and the potential for their reduction [1,2]. In 1999 the results obtained in 1996 were re-evaluated with an improved methodology. In this evaluation, the IPCC Guidelines for Good Practice in Inventory Preparation were strictly adhered to. The main results concerning SF_6 are summarised in this paper.

The paper first deals with current SF_6 emissions from different applications. As electric power supply and magnesium casting are the main topics of this conference, emissions from these sources are discussed in detail. Secondly, two emissions projections developed in our study will be presented. The reduction scenario does not include all technically feasible measures, but rather gives an estimate of what might be realizable in a shorter timeframe. Finally, an overview of measures in Germany, as assumed for the different scenarios, is given for each individual SF_6 sub-sector.

The conclusions summarise the SF_6 emissions reduction that has already been achieved, as well as the potential for further emission reductions as determined in the reduction scenario.

2 Consumption and Emissions of SF_6 in Germany – An Overview

In Germany, SF_6 emissions currently originate from the chemical's use in the following sectors:

electrical equipment
magnesium casting
semiconductor manufacturing
soundproof windows
car tyres
other applications

Electrical equipment for power supply was confirmed to be the most important SF_6 consumption sector in Germany. Although electrical equipment accounts for the highest annual consumption, the most important emission sources today are car tyres and soundproof windows. Compared to the emissions from these applications, emissions from magnesium casting, semiconductor manufacturing, and other applications are of minor relevance. Within the category of other applications, particle accelerators and military aircraft radar are among the biggest emission sources. Figure 1 shows SF_6 emissions by source.

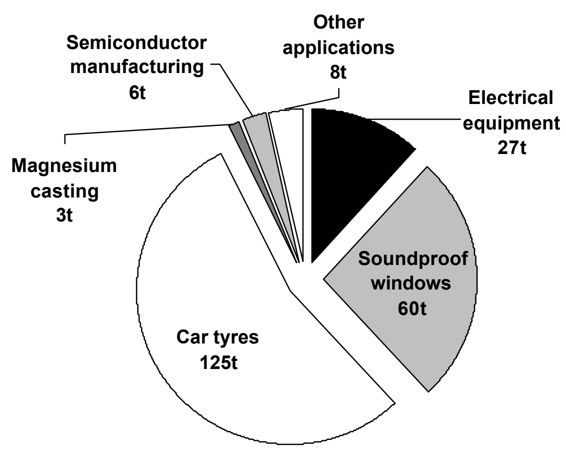

Figure 1: SF_6 emissions from different emission sources in Germany in 1998 (in t)

2.1 Electrical Equipment

In recent years, annual SF_6 consumption in the electrical equipment sector in Germany has been about 350-400 t. Of this amount, about 300-350 t were used in the manufacture of switchgear and 40 t were used for instrument transformers. Up to 1996, negligible amounts of SF_6 were used for power transformers. Sixty to seventy t of the SF_6 consumed remained in Germany. By far the largest proportion, about 80%, was exported as filling gas with electrical equipment. Because of the high export rate, emissions during manufacture exceed leakage and maintenance losses in Germany. A breakdown of SF_6 emissions from electrical equipment is given in Table 1.

Table 1: 1995-1997 SF_6 emissions in Germany during the manufacture and operation of electrical equipment (in t/a)

	1995	1996	1997
Emissions during manufacturing (production, testing…)	14.0	16.0	14.3
Emissions during installation (assembly emissions)	1.3	1.4	1.8
Continuous losses during operation (leakage and maintenance)	9.9	10.3	10.9
Total	**25.2**	**27.7**	**27.0**

2.2 Magnesium Casting

In magnesium casting, SF_6 is used as cover gas in order to prevent oxidation. In Germany, only magnesium casting of imported ingots takes place, not the processing of primary magnesium. From 1995 to 1997 the production volume in magnesium casting rose from 5,000 to 12,000 t in Germany. Over the same period the use of SF_6 as cover gas dropped from 6.1 to 3.0 t. As prescribed by the IPCC guidelines, our study assumed that consumption of SF_6 for magnesium casting equates with SF_6 emissions from this sector. Hence, emissions also dropped by half from 1995 to 1997. For 1998, SF_6 emissions were estimated to be 3.1 t.

3 Emissions Forecast

It is always difficult to forecast emissions. In order to forecast emissions by 2010, the following assumptions concerning the production rates were made for both scenarios.

1. For the electrical equipment sector, no substantial increase in production was assumed. Consumption of SF_6 was thus expected to remain between 350 and 400 t/a.
2. The magnesium casting output was expected to grow by 20% annually. Taking this into account, the annual output will rise to 73,000 t by 2010.
3. For the semiconductor industry, an annual growth of 6% was assumed. Unlike the rates for the two sectors above, the rate given for this sector refers to the growth in SF_6 consumption for etching, not to the increase in production volume.
4. The annual production of soundproof windows was assumed to remain at 2.6 million square metres of glazing.
5. As new car tyres are not filled with SF_6 any longer, the amount of car tyres produced is not connected with the consumption of SF_6 in this sector. Thus, no assumption was made.

3.1 Scenario I – Business-as-Usual Scenario

Under the assumptions of the business-as-usual scenario, annual SF_6 emissions are estimated to be 210 t, or 5.01 million t of CO_2 equivalents, by 2010. The business-as-usual scenario takes into account all measures already instituted since 1995. Table 2 indicates the SF_6 emissions determined under the assumptions of this scenario, by sector.

Table 2: SF_6 emissions in Scenario I, 1995-2010, by sector

	1995	2000	2005	2010
Electrical equipment	25	27	28	29
Soundproof windows	108	60	90	126
Car tyres	110	50	30	30
Magnesium casting	6	3	4	5
Semiconductor man.	4	6	8	11
Other applications	7	8	8	8
Total	**260**	**154**	**168**	**210**

3.2 Scenario II – Reduction Scenario

This reduction scenario assumes that full use is made of existing emission abatement technology. Furthermore, it takes into account additional policies and measures that are under discussion. Under this scenario, annual SF_6 emissions are projected to be 124 t, or 2.95 million t of CO_2 equivalents, by 2010. Table 3 shows this in a sector breakdown.

Table 3: SF_6 emissions in Scenario II, 1995-2010, by sector

	1995	2000	2005	2010
Electrical equipment	25	27	28	29
Soundproof windows	108	54	51	84
Car tyres	110	50	17	0
Magnesium casting	6	3	2	0.3
Semiconductor man.	4	6	6	2
Other applications	7	8	8	8
Total	**260**	**148**	**111**	**124**

4 Reduction Measures and Potentials in Germany

4.1 Electrical Equipment

Although the stock of SF_6 in electrical equipment in Germany has been growing by approximately 60 t/a, emissions remained constant at ±26 t/a in the period 1995-1998. This is due to the relatively low emission rates of approximately 4% during production of the equipment and systems (plant emissions), losses of about 2% during assembly, low losses due to leakage and during servicing when the equipment is in operation, and avoidance of emissions during disposal. Leakage rates of 1-3% during operation are permitted under international and national standards, but in practice only equipment manufactured before 1980 is in this range. New electrical equipment is tighter. For the emission projections, emission rates were determined to be 0.6% for equipment manufactured until 1995 and 0.4% for equipment manufactured after 1995. Losses during servicing can be kept low by using techniques that limit releases when the gas space is opened. Removal and refill take place in a closed cycle. On-site recycling is the state of the art. In terms of reduction measures and reduction potential, the more interesting period is the time after 2010. Assuming a lifetime of 40 years for SF_6 filled equipment, this is the time when the first generation will be disposed of. In Germany in 1996, the VDEW and ZVEI, the German operators' and manufacturers' associations, issued a joint declaration in which they undertook to recycle spent SF_6 [3]. A concept for the reuse of the SF_6 gas has been developed by Solvay Fluor und Derivate GmbH in co-operation with DILO Armaturen und Anlagen GmbH. The spent gas will be regenerated to "new gas that corresponds in all points to the DIN IEC 376 standard for new gas" [4]. The annual fillings of about 40 t will then be captured and consigned to reprocessing or disposal with minimum losses. As this will happen after 2010, the SF_6 emissions reduction resulting from this measure has not been included in the reduction scenario.

The declaration of the German operators' and manufacturers' associations also includes a commitment to provide the German Federal Ministry for the Environment, Nature Conservation, and Reactor Safety and the Federal Environmental Agency with data that are used to compile an (annual) SF_6 monitoring report. Through this agreement, we get data from both the equipment users' side and the manufacturers' side, as follows:

Utility side (covering 75-80% of total SF_6 in high voltage equipment):

1. Total amount of SF_6 in existing equipment
2. Quantity of SF_6 used for new installations in the reporting year
3. Return of SF_6 to the SF_6 producer (external recycling)
4. SF_6 purchases (= P)
5. Stock of SF_6 at the end of the year (= S)
6. Amounts of used SF_6 for disposal
7. SF_6 returned after on-site recycling (internal recycling) (= RI)
8. Quantity of SF_6 used for refilling (= R)

Manufacturer side (covering 95-98%):

1. Sales of SF_6 for new equipment in Germany
2. Sales of SF_6 for maintenance in Germany
3. SF_6 losses at installation on site in Germany (assembly emissions) (= LE)
4. SF_6 losses during manufacturing (plant emissions) (= LP)
5. Quantity of SF_6 returned from utility side
6. Amounts of used SF_6 for disposal
7. Total purchases of SF_6

Leakage and maintenance losses for the year "n" are calculated as given in equation 1 and total emissions (= TE) are calculated by summing up the individual emissions as shown in equation 2. Figure 2 tries to show a graphic outline of the SF_6 monitoring concept.

(1) $R_n = S_{n-1} + P_n + RI_n - S_n$

(2) $TE = R_n + LE + LP$

Although the gas contained in equipment will be captured and consigned to reprocessing or disposal at the end of the equipment's service life, emissions cannot be assumed to be zero. As the first generation of electrical equipment will not be scrapped until after 2010, we do not yet have any experience or data on these recovery losses.

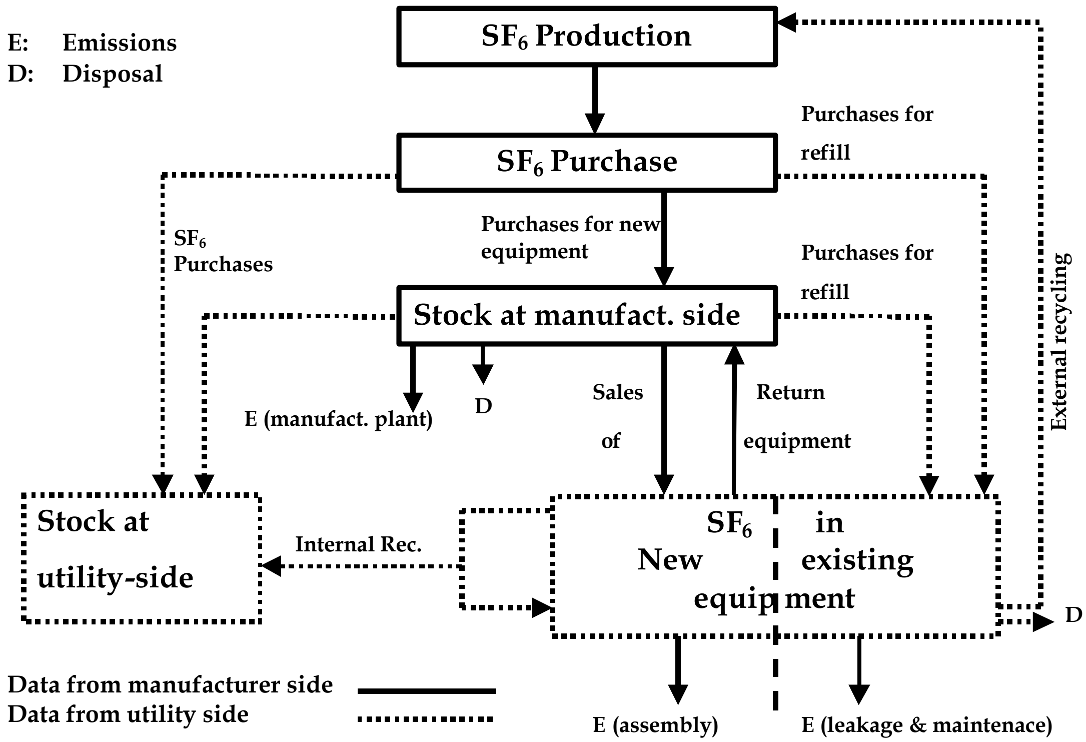

Figure 2: **Monitoring of SF_6 emissions from electrical equipment in Germany**

4.2 Magnesium Casting

In 1995, the output of the around 20 magnesium casting companies was 5,000 t. Of this amount, 2,000 t were produced with SF_6 as cover gas, while 3,000 t were already cast with SO_2. In old foundries the consumption of SF_6 was 2-3 kg per tonne of magnesium.

Although **Scenario I** is a business-as-usual scenario, SF_6 emissions are forecast not to increase, but rather to remain constant or even to decrease from 1995 onwards. SF_6 emissions from magnesium casting were estimated to total 5 t in the year 2010. A measure that is already included in this scenario is the conversion from SF_6 to SO_2 that was implemented by some casting companies between 1995 and 1998. Secondly, four modern foundries using new SF_6-saving furnace technology have been established. Specific SF_6 consumption at these foundries amounts to only 25-30 g SF_6 per tonne of magnesium cast. The plants belong to the car manufacturing industry, foreseen to be the most important consumer of magnesium in future, and its component suppliers.

For the reduction scenario, **Scenario II,** it was assumed that most of the small companies will switch over to SO_2 as cover gas. In addition, new large-scale foundries will use SF_6 substitutes from 2002 onwards, while existing foundries will replace SF_6 from 2005 onwards. Under these assumptions, SF_6 emissions will be about 0.3 t in the year 2010, although the annual output will rise to 73,000 t.

Our current outlook regarding future SF_6 emissions reduction measures is that for safety reasons new large-scale foundries will tend to prefer SF_6-saving furnace technology as long as no other alternatives are available. Only some small companies will switch over to SO_2.

4.3 *Other Important SF_6 Applications in Germany*

4.3.1 Soundproof Windows

In 1975, soundproof double glazing windows were introduced, into which SF_6 was filled in order to improve the sound insulating effect. Until the mid 1980s, SF_6 alone was used to fill the pane interspace. As a result of stricter thermal insulation requirements, SF_6 was then increasingly superseded by blends of argon and SF_6 in newly manufactured windows. The average proportion of SF_6 in the blends was 75% in 1995, but in 1998 it dropped to 33% as a result of the Heat Insulation Ordinance (Third Ordinance under the Federal Emission Control Act). This measure was included in **Scenarios I and II.** For all calculations, losses of 33% for filling of equipment, stock leakage losses of 1%, and disposal losses were assumed. For the forecast of disposal losses, a lifetime of 25 years was taken as a basis. As a ban on SF_6 for this application is currently being discussed, for the **reduction scenario, Scenario II,** it was assumed that SF_6 will be gradually phased out over the period 2000 to 2005. This will have an effect on filling losses from 2000 onwards and will also affect stock leakage losses. A mandatory recovery of SF_6 at the time the windows are scrapped can currently not be regarded as realistic and is therefore not included in the **reduction scenario.**

4.3.2 Car Tyres

In Germany, SF_6 has been used as filling gas in car tyres since 1984 in order to stabilise tyre pressure. More than 1 kg of SF_6 is used to fill a set of 4 tyres. The SF_6 consumption for this application rose, from 1984 to 1995, to 125 t and then dropped again. The decrease in SF_6 consumption for tyres has partly been a result of information on the global warming effect of SF_6. In contrast to **Scenario I** (business-as-usual), it was assumed for **Scenario II** that SF_6 will be phased out in this application by 2007 at the latest. As this gas is still used and recommended as filling gas in car tyres by some suppliers (e.g., car repair shops), a statutory ban might be the only way to achieve this objective.

5 Conclusions

Five sectors were identified as the most important consumers and/or emitters of SF_6 in Germany. SF_6 emissions originating from these sectors dropped from 253 t in 1995 to 221 t in 1998. This resulted partly from a change in the argon:SF_6 filling ratio in soundproof windows, which in turn was a result of more stringent thermal insulation requirements. Secondly, increasing costs for SF_6 influenced its use in this sector.

Although we saw a considerable increase in production rates, SF_6 emissions from magnesium casting dropped by half and emissions from electrical equipment did not increase significantly. This was achieved through improved technologies, tighter systems, and low maintenance losses.

Our business-as-usual scenario forecasts that total SF_6 emissions in 2010 will amount to 210 t/a, that is, 50 t less than in 1995. Taking into account further measures, as in the second scenario, we identified potential for a further reduction in SF_6 emissions of 86 t/a, or 2.0 million tonnes of CO_2 equivalents, by the year 2010. Although the time after 2010 was not considered in our study, it was pointed out that from this time an additional SF_6 emission reduction of 40 t per annum will be achieved due to the recycling of SF_6 from electrical equipment at the end of its service life.

6 References

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