GLOBAL EMISSION SOURCES OF GREENHOUSE GAS EMISSIONS FROM INDUSTRIAL PROCESSES: SF_6

ACKNOWLEDGEMENTS

This paper was written by Jos Olivier and Joost Bakker (RIVM, The Netherlands). Jan Willem Wouda (Elin Holec, Amersfoort), Rainer Bitsch (SIEMENS, Erlangen, Germany), and Manfred Maiss (formerly at MPI, Mainz, Germany) have reviewed the contents of this paper.

1 INTRODUCTION

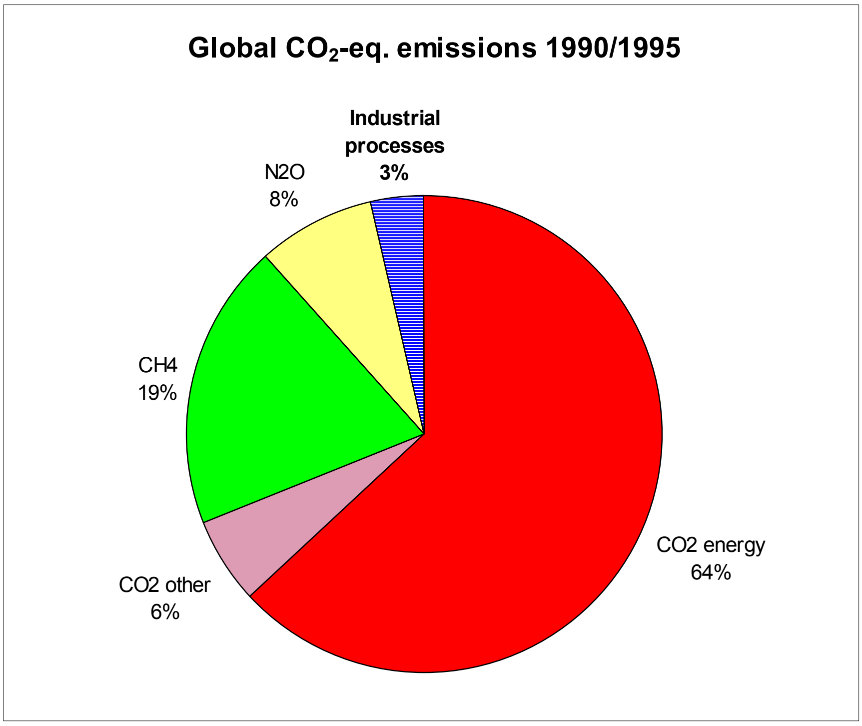
This Supporting Information Paper provides a more comprehensive picture of global SF_6 emissions, by putting them in the broader perspective of total global emissions from industrial non-combustion processes and of total global emission trends of greenhouse gases. In addition, the magnitude and regional distribution of the various SF_6 sources is discussed as well as the recent 1990-1995 trends of global total emissions per source category. The paper concludes with a review of available emission factors for SF_6 and their uncertainty (order-of-magnitude, based on expert judgement).

2 MAGNITUDE OF INDUSTRIAL PROCESS SOURCES

Greenhouse gas emissions from industrial processes are presently about 3% of global total CO_2-eq. emissions (Figure 1). However, this trend is increasing as illustrated in Figure 2, showing the trend in global total greenhouse gas emissions from 1980 to 1997.

If we look more closely at global industrial emissions of CO_2, CH_4, N_2O, and the 'new' gases HFCs, PFCs and SF_6, then it shows that about half of them stem from CO_2 emissions related to cement - clinker - production, about one-fifth can be attributed to adipic acid and nitric acid production and one-third stem from the three new gases, each with approximately equal contribution of about 10% (Figure 3). Here we have neglected other sources of CO_2 other than cement production, other sources of N_2O and other HFC compounds other than HFC-134a and HFC-23. Thus we may conclude, that at *global* level *presently* the industrial process emissions account only for a very minor share of 3%, and the new gases for about 1%. However, for particular countries the share in the national total may be quite different of course, depending on the presence of particular sources or not.

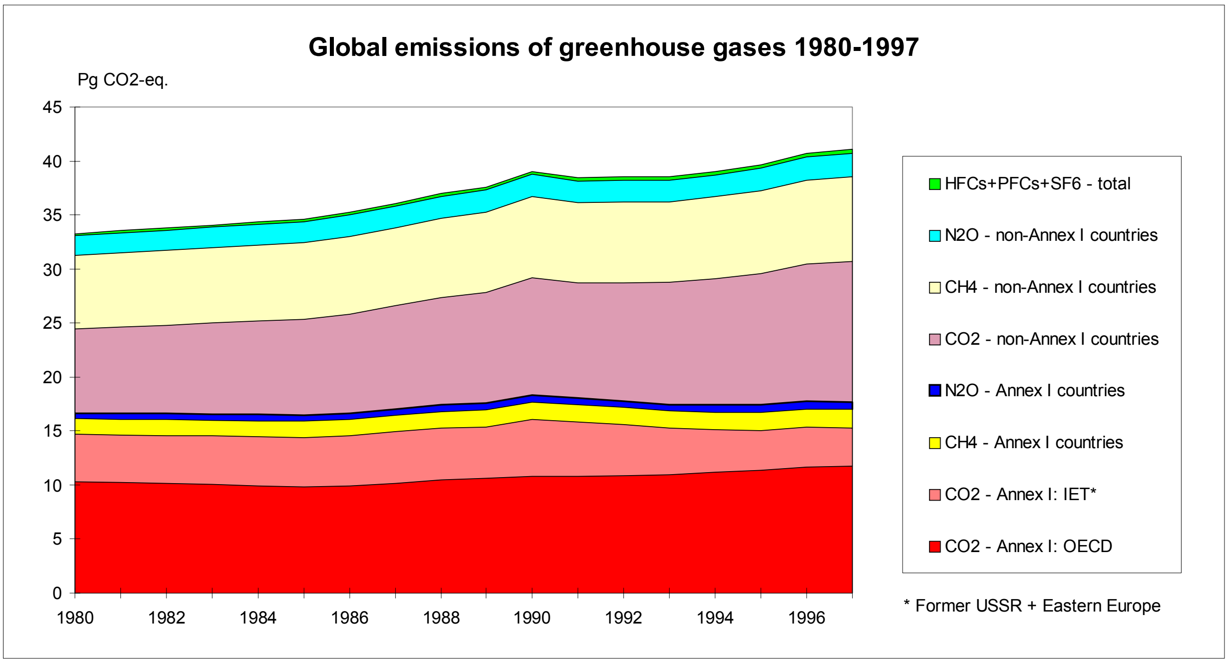
Figure 1 Global total greenhouse gas emissions in 1990/1995



Sources: CO_2, CH_4: EDGAR V2.0; N_2O: Mosier & Kroeze, 1998;

HFCs: Olivier & Bakker, 1999; PFCs: Harnisch et al., 1996; SF_6: Maiss & Brenninkmeijer, 1998

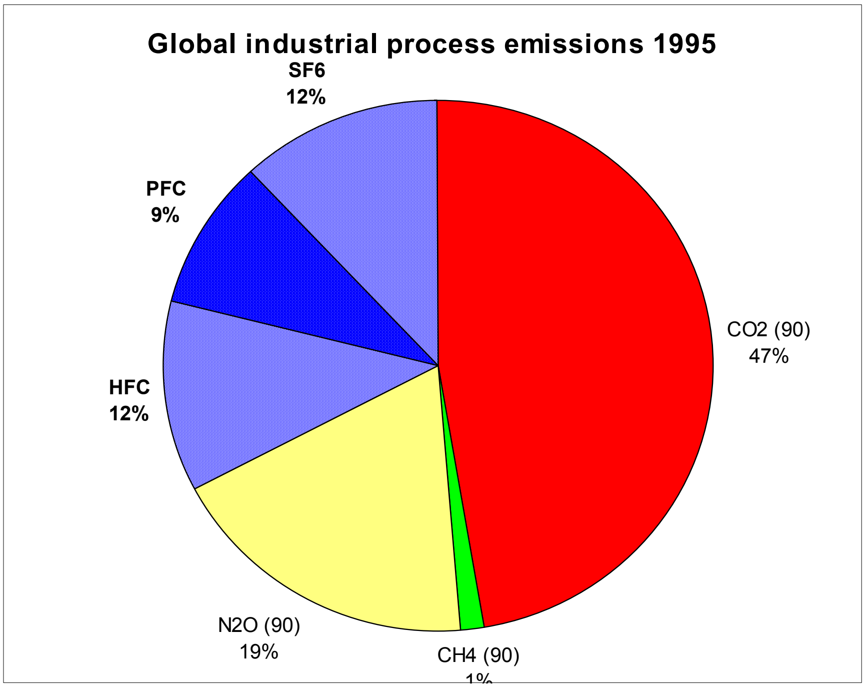
Figure 2 Global emissions of greenhouse gases 1980-1997



Note: Emissions of CH_4 and N_2O are very uncertain.

Sources: RIVM, 1998. Data sources used: EDGAR V2.0 (Olivier et al., 1996) (CO_2, halocarbons 1970-1990); IMAGE 2.0, 1994 (CH4, N_2O 1970-1990); BP, 1998 (CO_2 1990-1997); World Bank, 1998; FAO, 1998 (CH_4, N_2O 1990-1997); USGS (CO_2), AFEAS and own estimates.

Figure 3 Global industrial process emissions in 1995 by compound



Sources: CO_2, CH_4, N_2O: EDGAR V2.0

HFCs: Olivier and Bakker, 1999; PFCs: Harnisch *et al.*, 1996; SF_6: Maiss and Brenninkmeijer, 1998

3 MAGNITUDE AND DISTRIBUTION OF SF_6 SOURCES

Emissions of SF_6 are virtually all of anthropogenic origin (Harnisch *et al*., 1996). Estimation of global historical emissions of SF_6 can be based on a survey of global annual sales per application conducted by an independent auditor, Science and Policy Services (S & PS, 1997). In this survey, in which the six major manufacturers co-operated, the following applications are distinguished:

- Electricity sector (separating Utilities and Equipment manufacturers), with applications in Gas Insulated Switchgear (GIS) and Circuit Breakers, while some others include gas-insulated high-voltage transmission lines and mini-stations; in addition 'Utilities' also includes the application of SF_6 in accelerators (for scientific and/or military purposes);
- Magnesium industry (primary production and die casting), with application as a cover gas in foundries for die casting to prevent oxidation of the molten magnesium;
- Electronics industry, where SF_6 is commonly used in semiconductor (chip waver) manufacturing processes for either plasma etching or as an etchant before chemical vapour deposition (CVD);
- Adiabatic property applications, notably in tennis balls, shoe soles and in truck tyres. The latter is assumed to occur only in Germany, and
- Other applications, such gas-air tracer in research and leak detectors, for medical purposes, electronic applications, soundproof windows, degassing aluminium specialties etc.;

Usage for soundproof windows (double glazing) predominantly occurs in Germany, but a small fraction of this application also occurs outside Germany, e.g. in neighbouring countries. Furthermore, use in primary aluminium production to degas aluminium specialties occurred only during some years in the 90's (Maiss and Brenninkmeijer, 98); apparently the process was not found to be beneficial. Finally, in addition to consumption, production of SF_6 also gives rise to some inadvertent emissions (to the order of 0.1% of the amount of SF_6 produced).

Historical global total emissions have recently been estimated from the trend in historical atmospheric concentrations and was matched with the results of the S & PS survey, combined with a few corrections for some periods, including estimated amounts for Russia and China, not included in the survey (Maiss and Brenninkmeijer, 1998). By and large, the global total annual emissions could be estimated fairly well by assuming 100% emissions from all categories mentioned above except for the electrical equipment manufacturers and sound proof windows sub-categories, where global annual emission percentages of 31 and 50%, respectively, were assumed.

Measured concentrations could be matched best when a delay in total emissions of 8 months was included. This was a top-down approach based mainly on the global S & PS inventory. In a subsequent discussion, the authors noted that there is a marked difference between the electrical equipment market in North America versus Europe and Japan. The amount of SF_6 consumption in North America and Europe estimated by two key SF_6 manufacturers could not be reconciled with the amounts per application of the S & PS survey. Maiss and Brenninkmeijer concluded that part of the consumption attributed to the electrical utilities could be used for other applications, possibly in the magnesium industry such as utilities that also own magnesium production facilities.

In a subsequent effort to reproduce the historical emission trends of Maiss and Brenninkmeijer from a bottom-up analysis of national activities, starting with the modified S&PS inventory by Maiss and Brenninkmeijer (1998), Olivier and Bakker (1999) made an estimate of national use and emissions of SF_6 per source category. Out of a global total of about 8 350 tonnes of SF_6 consumption in 1995, the following distribution over source categories was made:

- Original electrical equipment manufacturers: 3,500 tonnes (42%), which was composed as follows: 140 - USA; 1,200 - Europe; 1,400 - Japan; 500 - Russia; and 350 - China;
- Refill by electricity utilities: 1,500 tonnes (18%), of which 700 - USA and 400 and 370 from equipment made by European and Japanese manufacturers, respectively (from a total stock of 3,500, 11,000 and 10,600 tonnes, respectively);
- Magnesium industry: 400 tonnes (5%) [according to the SPS survey], of which 260 - USA, Canada - 60 and Norway - 35;

- Semiconductor industry: 300 tonnes (4%), of which 120 - USA and 120 - Japan;
- Truck tyres: 140 tonnes (2%), allocated to Germany;
- Tennis balls, soles of sporting shoes: 220 tonnes (3%), of which 110 - USA and 70 - Japan;
- Soundproof windows: 270 tonnes (4%), with a total of 1,700 in stock, predominantly in Germany;
- Other applications: 340 tonnes (5%), of which 90 - USA, 50 - Japan and 25 – Germany, and
- Miscellaneous applications labelled 'Utilities': 1,700 ± 600 tonnes (23%), of which 1,200 ± 400 - USA and 500 ± 200 - Europe, part of which could be (a) scientific applications, (b) military applications, (c) additional refill of utility equipment or (d) additional consumption for magnesium production (may be the largest part according to Maiss and Brenninkmeijer).

4 ESTIMATED GLOBAL SF_6 EMISSIONS BY CATEGORY

For calculating emissions for each of the categories, the following specific assumptions were made by Olivier and Bakker (1999) for historical emissions up to 1995:

- Electrical equipment manufacturers: 30%-12% (prior to 1990 as compared to since 1995, respectively), 35% and 50% emitted of the amount used during manufacturing and on site during erection and commissioning by European, Japanese and other OEM, respectively, and for the circuit breaker manufacturers in the USA 55% for the years leading up to 1970 was used, decreasing to 29% in 1995;
- Electrical utilities: it is assumed that the lifetime of GIS and other electrical SF_6 applications is 30 years, with a leakage rate of the stock of 5% per year before 1980 and 3% for subsequent years for newly installed equipment. This is mainly due to handling losses during erection and commissioning at the site, accidents and losses during maintenance. An exception is made for the USA where 20% stock losses-refill were assumed for 1995, increasing to 41% in 1970;
- Magnesium production: it is assumed that SF_6 is used in all OECD countries proportional to total primary and secondary magnesium production figures and that all SF_6 consumed is emitted promptly. However, it is known that the actual consumption, thus emission, per ton of magnesium produced may vary by a factor of 100 (Gjestland and Magers, 1996);
- Adiabatic property applications: for tyres a delay in emissions of 3 years is assumed; for other applications such as shoe soles and tennis balls the same delay time was used (Schwarz and Leisewitz, 1996), and
- Electronics industry: a delay of one year is assumed, i.e. 50% is emitted in the same year and 50% is emitted in the year after the sale;

Other applications:

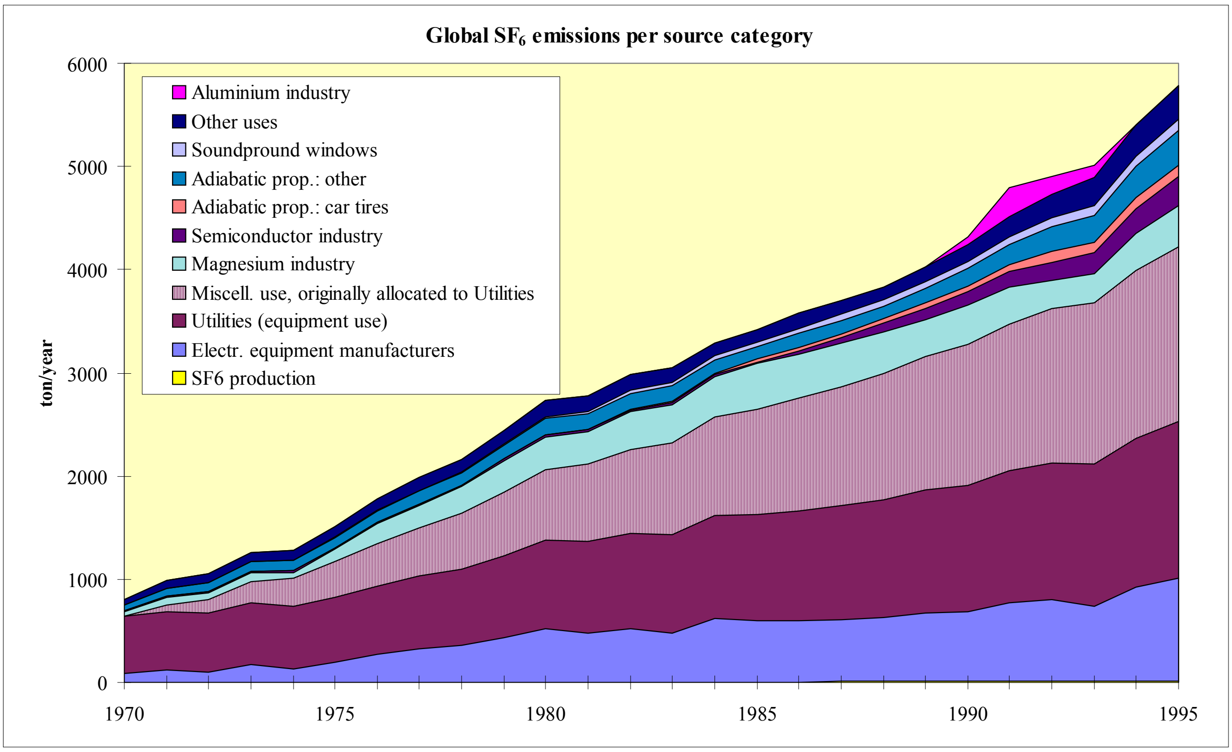
(a) For double glazing of soundproof windows, it is assumed that 33% of the SF_6 is released, from the amount purchased, during fabrication (filling of the double glass window). For the remaining stock contained inside the window an annual leakage rate of 1% of the stock is assumed for a period of 25 years, with application in windows since 1975 (Schwarz and Leisewitz, 1996).

(b) For all other applications a delay of one year is assumed, i.e. 50% is emitted in the same year and 50% is emitted in the year after the sale.

(c) Furthermore, for application in aluminium production different information is available, as some authors assume that all SF_6 is emitted (IPCC, 1997; Maiss and Brenninkmeijer, 1998) while others claim that virtually no SF_6 emissions occur, since most of the SF_6 is decomposed when reacting with aluminium (Victor and MacDonald, 1998). After checking with the patent description it is concluded that all SF_6 used will be emitted.

In summary, global total emissions per application follows the same pattern as consumption, except for original equipment manufacturers (OEM), where emissions are 28% (USA), 30% prior to 1990; 12% since 1995 (Europe), 35% (Japan) and 50% (other) of annual consumption, and soundproof windows, where manufacture emissions are 33% and subsequent leakage is 1% annually. Emissions of truck tyres and sport attributes are assumed to have a three years delay. Global total emissions in 1995 as observed from concentration measurements were estimated at 6,060 ± 200 Gg by Maiss and Brenninkmeijer (1998), which is in agreement with 5,900 ± 200 Gg SF_6 derived by Geller *et al.* (1997) from a broader atmospheric measurement dataset and using a new calibration scale. Olivier and Bakker estimated global total SF_6 consumption at 8,250 tonnes and total resulting SF_6 emissions at 6,060 tonnes or 73% in 1995. Resulting emissions per application are shown in Figure 4. These emissions represent 0.4% of present global total greenhouse gas emissions, of which the electricity sector contributes about half.

Figure 4 Global historical SF_6 emissions by end-use categories



Manufacturing of GIS is mainly done in Western European countries and Japan, whereas manufacturing of other electrical applications such as circuit breakers is mainly in North America. In the utility sector, GIS applications predominantly are used in Europe, Japan and countries in the Middle East. However, SF_6 containing circuit breakers, so-called dead tank, are mostly used in the USA and Canada. Use in the magnesium industry is concentrated in the USA and other primary producing countries and the magnesium die casting industry that seems to be concentrated in countries with car parts manufacturing industry. SF_6 containing tennis balls, sporting shoes etc. are assumed to be only used in OECD countries, whereas SF_6 use in truck tyres and sound proof windows occurs only in Germany and some neighbouring countries.

The analysis by Maiss and Brenninkmeijer (1998) and by Olivier and Bakker (1999) suggests that in most cases a fair estimate of global annual emissions from equipment in use can be made. Such an estimate can be in agreement with atmospheric observations. This can be based on estimates per type of equipment (GIS, circuit breakers, etc.) as follows:

(a) the total amount in national stock in equipment ;

(b) the amount annually purchased for refill (= compensation for leakage and maintenance losses), and

(c) information on SF_6 use for newly installed equipment. In case the contribution is considered to be relatively large, a special survey could be conducted to get accurate activity data for the sector.

For OECD countries, at present about 20% of global total emissions cannot be properly allocated to one of the main source categories. Therefore it could be recommended that countries carry out one basic survey of all national sources of SF_6 emissions, that can subsequently be used for monitoring of activity data, emission factors and other relevant variables.

5 RECENT EMISSION TRENDS OF SF_6 SOURCES

Olivier and Bakker (1999) estimated the growth in emissions in **tonnes** per application 1990-1995 (including Russia and China) as follows:

SF_6 producers:	2	(+30%)
Equipment manufacturers:	320	(+50%)
Electricity sector:	290	(+25%) (estimated, after correction for miscellaneous)
Miscellaneous:	340	(+25% (estimated)
Magnesium industry:	14	(+5%)
Semiconductor industry:	150	(+120%)
Adiabatic properties: truck tires	50	(+90%)
Adiabatic properties: other:	160	(+100%)
Soundproof windows:	40	(+60%)
Other use:	170	(+100%)
Aluminium industry:	-70	(-100%)
Net total:	1460	(+34%)

Although the electronics industry showed the largest growth rates, the electrical equipment manufacturers was the dominating consumption sector with 5-year growth rates of about 50%. However, since 1995 there has been a distinct change in the trend due to the market introduction of new and quite different technology (e.g. using 50% lower pressures), resulting in substantially less use of SF6 per unit.

6 REVIEW OF AVAILABLE EMISSION FACTORS FOR SF_6

Within the electricity sector (equipment manufacturers and utilities) one can distinguish four phases:

(a) production in equipment plant (manufacturers);): handling, filling/testing, recovery;

(b) erection on site (commissioning by manufacturer or utility): handling, filling;

(c) usage by utilities: (leakage, maintenance/venting, stock-refill), and

(d) disposal by utilities: venting or recovery.

SF_6 containing electrical equipment is mostly Gas Insulated Switchgear (often > 90% of sectoral SF_6 use), except for North America, where mostly (>90%) circuit breakers/dead tank equipment is being used, with different emission factors. GIS manufacturers are concentrated in Western European countries and Japan, whereas dead tanks are mostly manufactured and used in the USA.

If countries do not have representative country-specific information on emission factors, delay factors etc. available, they could either use *current* default values as recommended by the *Revised 1996 IPCC Guidelines for National Greenhouse Inventories* (*IPCC Guidelines*) (IPCC, 1997) or *updated* global or regional default emission factors based on more recent information compiled by industry organisations (e.g. CAPIEL/UNIPEDE, 1999). These values should be based on a compilation of a consistent set of factors derived from global and regional information which has been checked by a top-down versus bottom-up comparison of global annual emissions (i.e. concentration derived emissions versus per source/region/country estimated emissions). For so-called prompt emission categories, calculation of annual emissions, e.g. as described by Maiss and Brenninkmeijer and by Olivier and Bakker, respectively, taking into account some delay between purchase and actual use of 6 months may be recommended. This is similar to approaches generally used in scientific models for calculating emissions of ozone depleting substances (Midgley and Fisher, 1999) and the time delay that was concluded by Maiss and Brenninkmeijer (1998) when fitting the adjusted S & PS data against the observed atmospheric concentrations.

The ***IPCC Guidelines*** recommend the following default emission factors for SF_6:

- **Fugitive emissions** are not considered for SF_6. However, for HFC and PFC a default of 0.5% of total production of the compound is recommended, based on the default rate used for fluorocarbon processes (UNEP, 1994).
- **GIS and circuit breakers -** emissions consist of (each year 1%) of the total quantity contained plus 70% (or more precisely: 74%) of the quantity of equipment manufactured in year t-30 (assuming a lifetime of 30 years and release upon disposal) (NILU, 1993). Also, the Guidelines note that 'If data on total stock of GIS are unavailable, then it should be assumed that emissions equal consumption.'
- **Fire suppression and explosion protection** - some of the new substitutes for halon in fire extinguishing equipment contain SF_6, probably in blends with HFC. If products contain SF_6, it is emitted in the same manner as HFC or PFC. Recommended defaults for these emissions from mature markets are as follows: 60% of the total quantity used in new portable equipment and 35% of the total quantity used in new fixed (flooding) equipment. This is based on halon emissions from these type of applications (McCulloch, 1992). The Guidelines recommend that SF_6 emissions are calculated according to the proportion of SF_6 in the blend.
- **Other applications** - neither method nor defaults are given.

We will now review the currently available emission factor data to be applied for SF_6:

(a) Fugitive emissions from production

UNEP (1994) mentions a range of 0.1-1.0% for CFC production and 0.5% for well-designed and well-managed facilities. For the production of carbon tetrachloride (CTC), a survey by European, US and Japanese manufacturers indicated an emission rate of 0.1%. This number is consistent with the production of a liquid, rather than a low boiling point gas (like CFCs) (UNEP, 1994). Contacts with manufacturers suggested that for inadvertent losses during production of $SF_{6,}$ default emission factors of 0.1% of total production could be recommended.

(b) GIS and circuit breakers

Initiatives of the industry started some years ago. In particular, a joint UNIPEDE/CAPIEL working group (UNIPEDE/CAPIEL, 1998) assessed the present situation within Europe. It concluded that in 1995 about 4,100 tonnes of SF_6 were installed in high-voltage switchgear in Europe (almost all GIS and predominantly in Western Europe) and that about 1,200 tonnes were purchased in 1995 by GIS manufacturers for use in new switchgear - included for export outside the EU). At present within the EU filling and handling emissions during manufacturing in the factory and on site during erection and commissioning are estimated at 12% of the total amount purchased by the manufacturers. According to CAPIEL/UNIPEDE (1999), of this 12% about half is emitted during manufacturing and the other half is emitted on site. Based on a comprehensive enquiry, it is estimated that total emission from GIS equipment in service due to leakage and maintenance is about 3% of the 4 100 tonnes installed. For the newest equipment, leakage rates only (i.e. excluding maintenance losses) are of the order of 0.5% per year. According to the industrial standard IEC 694 (IEC, 1996), equipment manufactured before 1980 has a maximum leakage rate of 3% and for newer equipment this value is 1%.

A Technical Committee of ETRA has examined the present situation in Japan (Takuma, pers. comm., 1998) and concluded from a survey that GIS manufacturing, erection and commissioning emissions in Japan in the period 1990-1995 were about 40% of the total amount of SF_6 purchased by the manufacturers. On-site measurements showed that the leakage rate is below 0.1% per year. In addition, there are emissions during maintenance (inspection), replacement and withdrawal. During maintenance current practice is that overall 60% of the SF_6 is recovered (70% of GIS > 100 kV and 0% of GIS < 100 kV). At present total stock emissions are estimated at about 1% of total installed stock of 6 200 tonnes in 1995. In addition, in Japan about 400 tonnes were used in 1995 for insulating high-voltage cables (Maiss and Brenninkmeijer, 1998).

For the USA, the market is dominated mostly by ***circuit breakers***. According to NEMA, in 1995 switchgear manufacturers purchased 140 tonnes of SF_6, of which 28.5% was estimated to be emitted during manufacturing, erection and commissioning (NEMA, 1997). Annual refill and leakage compensation in the USA was estimated to be 20% of a total installed stock of 3,500 tonnes in 1995.

When disposing of phased-out GIS, industry recommendations (e.g. IEC 61634 and CIGRE SC 23) provide guidelines for handling, recycling and reuse of SF6 aiming at maximum recovery. However, since GIS equipment has a lifetime of about 30 years and was introduced in the early '70s, under normal circumstances disposal of outdated equipment has not yet occurred.

(c) 'Other' application

We have identified the following applications with a distinct different emission profile:

- **Adiabatic property applications**

  For tyres a delay in emissions of 3 years is assumed; for other applications such as shoe soles and tennis balls the same delay time was used (Schwarz and Leisewitz, 1996).

- **Double glazing of soundproof windows**

  It was assumed that 33% of the SF_6 was released, from the amount purchased, during fabrication (filling of the double glass window) and the remaining stock contained inside the window an annual leakage rate of 1% of the stock is assumed for a period of 25 years, with application in windows since 1975. For all other applications a delay of one year is assumed, i.e. 50% is emitted in the same year and 50% is emitted in the year after the sale (Schwarz and Leisewitz, 1996).

- **Fire suppression and explosion protection**

  60% of the total quantity used in new portable equipment and 35% of the total quantity used in new fixed (flooding) equipment, based on halon emissions from these type of applications (McCulloch, 1992).

Thus, for all ***remaining other*** applications (except for magnesium production and use in the semiconductor industry) such as tracer, medical applications, etc., an average delay of one year is assumed, i.e. 50% is emitted in the same year and 50% is emitted in the year after the sale. This leaves the question of specific use in military applications and for accelerators. If no information is available, these should be dealt with as with the remaining ‘other’ applications (as semi-prompt emissions).

7 UNCERTAINTY IN EMISSION FACTORS

According to the Reporting Instructions in the *IPCC Guidelines,* reported uncertainty percentages should be interpreted as providing 2σ(standard deviations). In the case of a Gaussian distribution, 2 sigma corresponds with a 95% confidence interval. Note that in cases where the uncertainty is estimated to be more than ±50%, the interpretation of the lower percentage band of the range is not meaningful. As with the smaller uncertainties, this should be interpreted as the corresponding uncertainty factors: an uncertainty range between minimum value and maximum value.

We have compiled a list with estimated default uncertainty ranges for emission factors of SF_6, which have been selected from the following list of ranges, which are classified by a more or less fixed order-of-magnitude difference between subsequent values (Table 1):

TABLE 1

DEFAULT UNCERTAINTY RANGES FOR EMISSION FACTORS (SF_6)

Uncertainty (%)	Uncertainty factor (-)	Qualitative uncertainty
± 5	1.05	very small
± 10	1.10	small
± 25	1.25	medium
± 50	1.50	large
± 100	2.00	very large
± 200	3.00	extremely large

From the preceding discussion on recently available information, the following conclusions have been tentatively drawn regarding uncertainty ranges of emission factors, using expert judgement of the underlying data sources:

- ***SF_6 production*** default emission factor 0.1% of total production - uncertainty range 50%.
- ***GIS manufacturing*, site erection and commissioning**

  European manufacturers:

  - prior to 1995: 30% - uncertainty range 10%;
  - from 1998 onwards: 12%, of which about 1/2 is emitted during manufacturing and 1/2 on site (for each of the 6% - uncertainty range 25%);

Japanese manufacturers:

- prior to 1995: 35% - uncertainty range 10%
- from 1998 onwards 12% - uncertainty range 25%

- **G*IS leakage* plus maintenance**

European GIS, total:

- equipment manufactured before 1980: 5% - uncertainty range 25%
- newer equipment: 3% - uncertainty range 25%

Japanese GIS, total:

- equipment manufactured before 1980: 5% - uncertainty range 25%
- newer equipment: 1% - uncertainty range 50%?

All cases include leakage rates:

- of equipment manufactured before 1980: 3% - uncertainty range 50%
- of newer equipment: 0.5% - uncertainty range 100%

- ***Circuit breakers manufacturing*, site erection and commissioning**

- 55% for years up to 1970, decreasing to 29% in 1995 - uncertainty range 50%

- **Circuit breaker leakage plus maintenance**

- 20% of a total installed stock - uncertainty range 50%

- **Insulation of high-voltage transmission lines**

- unknown

- **Adiabatic property applications**

- for tyres: delay of 3 years - uncertainty range 25%
- for other applications: delay of 3 years - uncertainty range 100%

- **Double glazing of soundproof windows**

- release during fabrication (filling of the double glass window) 33% - uncertainty range 25
- annual leakage rate of 1% - uncertainty range 50%

- **For all other applications**

- delay of 1 year - uncertainty range 50%

- **Fire suppression and explosion protection**

- 60% of the total quantity used in new portable equipment - uncertainty range 25%
- 35% of the total quantity used in new fixed equipment - uncertainty range 25%

8 CONCLUSIONS

As shown by Maiss and Brenninkmeijer (1998), within their reconstruction of global SF_6 use and emissions, an average emission rate of about 30% from manufacturers is required to reproduce the atmospheric build-up of SF_6 concentrations. In parallel with the studies of Maiss and Brenninkmeijer and of UNIPEDE/CAPIEL, Bitsch has estimated total stock in GIS and other electrical equipment in 1995 for different world regions (Bitsch, pers. comm., 1998). This information, as well as regional consumption estimates by major SF_6 manufacturers and the subsequent analysis carried out by Maiss, have been used by Olivier and Bakker to reconstruct the annual emissions from the electricity sector. They calculated the estimated total stock in electrical equipment in the USA, Europe and Japan at about 3 500, 4 100 and 6 200 tonnes of SF_6, respectively (about 12 000 and 10 000 tonnes for Europe and Japan, including exported equipment). For total manufacturing, erection/commission emission rates for 1970-1995, 30%, 35% and 50% for European, Japanese and other equipment manufacturers was used, respectively, whereas for the USA 55% was used for years up to 1970 and decreasing to 29% in 1995. As for the leakage/maintenance rates, the following set was consistent with both stock assumptions in 1995 and required emission trends: 20% for equipment in the USA (consisting mostly of circuit breakers, dead tank type), and 5% for equipment manufacturers prior to 1980 and 3% from 1980 onwards. An additional assumption was that 100% of the annual consumption in the USA and Europe of about 1 200 and 500 tonnes, which is not accounted for in the utility sector, is emitted promptly. If part of these quantities would be used for stock building, then the emission rates for leakage/maintenance would have to be somewhat higher.

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