

**EPA Conference: SF₆ and the Environment, Emission Reduction Strategies.
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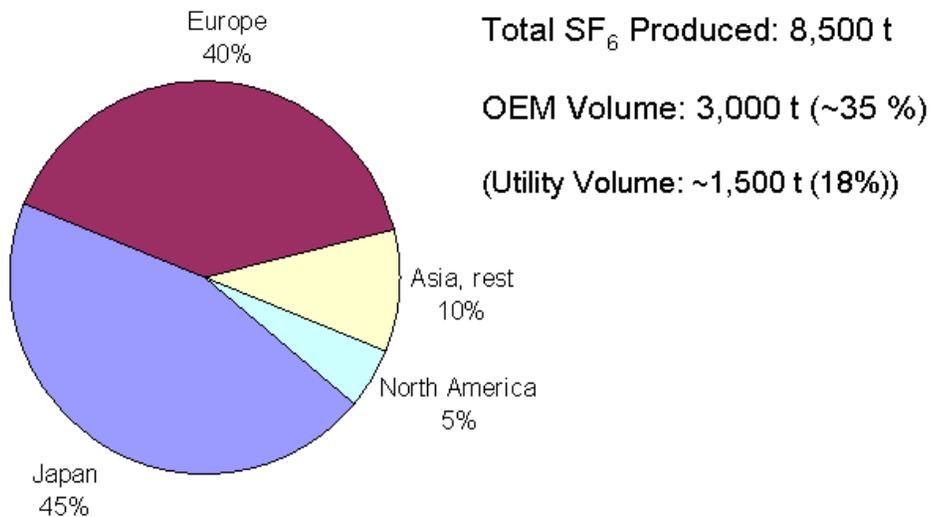
SF₆ Management and Handling by Switchgear Manufacturers and Users: An overview of the Situation in the European Union

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1 SF₆ and the switchgear technology

A substantial part of the SF₆ yearly produced worldwide is used in switchgear systems. Based on figures provided by the OEM's in Japan /1/ and Europe /2/ and taking into consideration a volume of SF₆ produced in 1995 (base year in the Kyoto protocol) of approx. 7,500 tons in the USA, Europe, Japan and South Africa, to which is added an approximated volume of 1,000 tons produced in Russia and China, it is estimated that the OEM's in Japan and Europe use approx. 45% resp. 40% of the volume purchased by the OEM's worldwide.

1995 OEM Volume



Taking into consideration an estimated volume purchased by the utilities of 1,500 tons for compensation of leakage and handling losses, the total share of SF₆ used for application in switchgear is some 55% of the SF₆ produced worldwide in 1995.

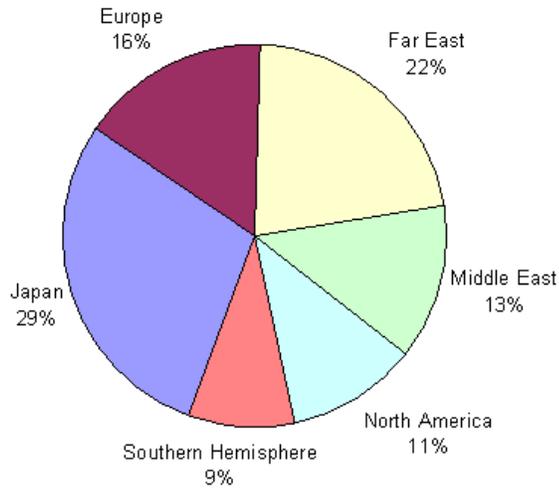
The SF₆ banked worldwide in switchgear in 1995 is estimated at 27,500 tons.

Derived from figures provided from Japan /1/, Europe /2/, as well as provided by switchgear manufacturers and from the Maiss & Brenninkmeijer paper /3/, the shares are given per area of the switchgear population

¹ CAPIEL is the Coordinating Committee for the Associations of Manufacturers of Industrial Electrical Switchgear and Controlgear in the European Union.

² EURELECTRIC (merged with UNIPEDE) is the Union of the Electricity Industry

1995 Switchgear Population

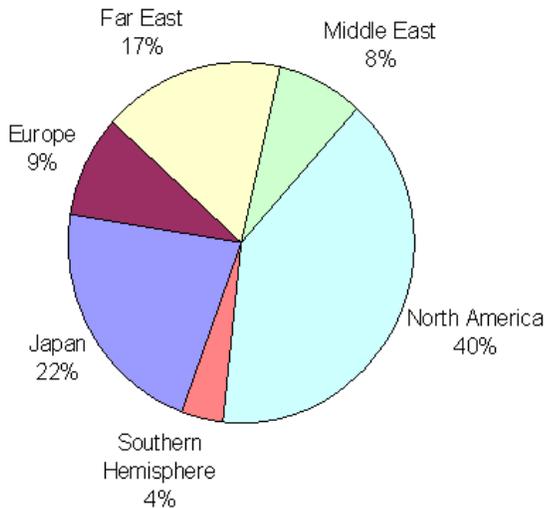


**SF₆ Worldwide Banked
in Switchgear: 27,500 t**

From a total amount of 6,200 tons of SF₆ emitted worldwide in 1995 /3/, it is estimated that the world switchgear related emission in 1995 was some 2,700 tons, representing approx. 43% of the total SF₆ emitted in 1995.

Main data for the emission figures originate from Japan /1/, Europe /2/, and USA /4/. Figures for the Middle East, the Far East and the Southern Hemisphere are estimated, based on amounts banked and installed in 1995 as well as on erection and handling procedures in place at the time

1995 Switchgear Related Emission



**Total SF₆ Worldwide
Emitted: 6,200 t**

**Total SF₆ Worldwide
Emitted, Switchgear
related: 2,700 t (~43%)**

It shall be noted that the figures mentioned are approximated. Its purpose is to give a general and broad overview, putting the individual figures into a worldwide perspective.

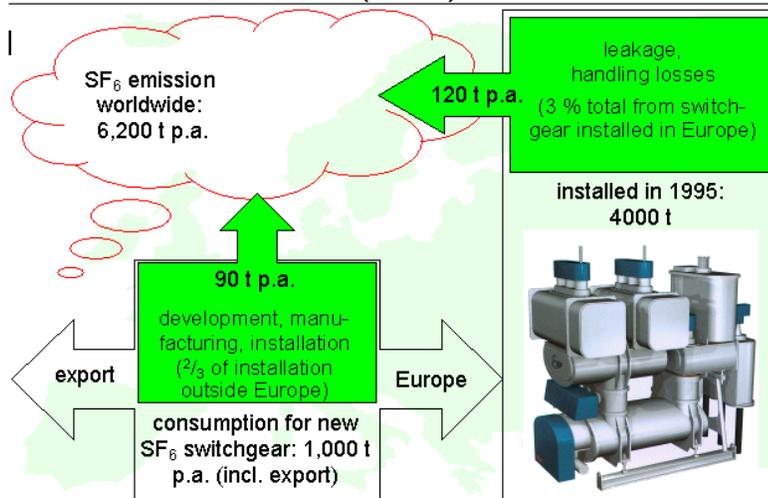
From the figures it can be seen that Europe is a relatively large consumer of SF₆ for application in switchgear, on the other hand that Europe is a moderate emitter of SF₆ in the sector.

2 Situation in the European Union

Extensive enquiries and data providing by Electricity Utilities and Switchgear Manufacturers in the European Union have given a good picture of the use and the emission of SF₆ applied in high-voltage switchgear in the EU.

In the Kyoto base year 1995, the total amount banked in the EU was about 4,000 tons and the quantity purchased by the manufacturers in the European Union for use in new switchgear (including that for export outside the European Union) was about 1,000 tons

SF₆ and the switchgear technology: Situation in the EU 15 (1995)



During the manufacturing process and also during erection and commissioning, a quantity of gas is inevitably emitted in the factory and on site due to filling and other handling manoeuvres. This level has been determined by enquiry in the European Union to be about 90 tons in 1995.

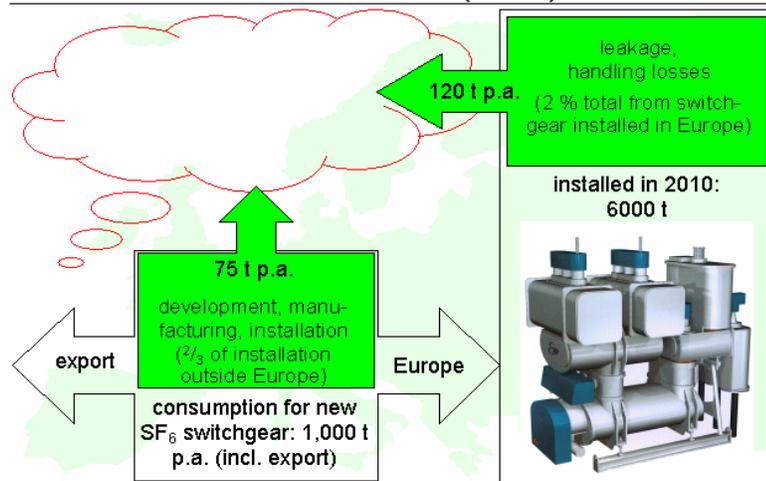
It is more difficult to obtain corresponding figures for emission in service due to the large number of locations involved. Using the results of a comprehensive enquiry, it is estimated that the total emission from equipment in service due to leakage and maintenance in 1995 was about 3% of the 4,000 tons installed. This gives a figure for emission in service of 120 tons in 1995

The total emission in the European Union from manufacturing and use was therefore about 210 tons in 1995. As the total estimated SF₆ emission in the world was about 6,200 tons in 1995 /3/, this value corresponds to approximately 3%.

In future, the total emissions arising from leakage will probably not change significantly, since reduced leakage rate resulting from improvements in technology will be offset to some extent by the growing population of switchgear in service (+ 50% until 2010). However, emission rates arising from the handling of SF₆ during testing, commissioning and maintenance should significantly decrease because of the progressive implementation of improved recovery procedures and processes.

It is estimated, taking into account growth in European and international markets, that in the year 2010, the total mass of SF₆ in switchgear installed in the European Union will be some 6,000 tons, and the average annual purchase by the switchgear manufacturers in the European Union will be about 1,000 tons

SF₆ and the switchgear technology: Future situation in the EU 15 (2010)



Emissions from these activities are expected to be in total lower in 2010 than in 1995, i.e. a total of 195 tons compared to 210 tons in 1995.

3 Options for SF₆ Emission Reduction.

Basically the activities in the European Union are concentrating on two main issues:

- Improvement of awareness at all levels of SF₆ handling. For that intensive training is necessary at manufacturers and users.
- Improvement of handling equipment and procedures.

An example of three different handling procedures clearly shows that only with appropriate gas handling equipment handling losses can be minimised.

For an imaginary GIS compartment of 1,000 litre, filled with SF₆ (~3 barg, 4 bara), the emission of SF₆ will vary:

- No gas Handling Unit → Loss 25 kg = 100% emission.
- Simple Gas Handling Unit, Extraction down to 500 mbar → Loss 3- 4 kg = 10-15% emission.
- Sophisticated Gas Handling Unit, Extraction to below 10 mbar → Loss 75 g = ~ 0,3% emission.

It is interesting to note from a presentation at the conference by a gas handling equipment manufacturer that these units are now readily available.

Given the fact that emission of SF₆ in the EU is to a large extent (80-90%) due to handling of SF₆ at various stages of its application, further reduction of leakage from switchgear in general is considered as the least effective but most costly option for reduction of emission.

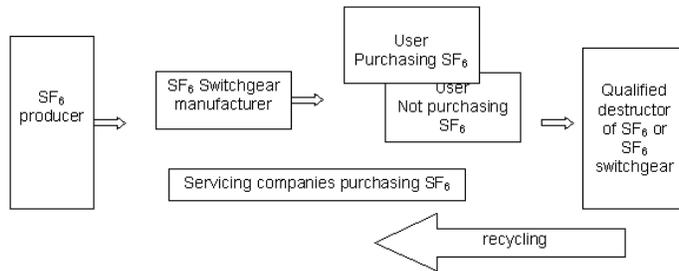
4 Inventory Methodology for SF₆ in Switchgear

With the aim to develop the measures and tools for further controlling of SF₆ emission from in particular handling of switchgear, and at the same time to comply with the demands of UNFCCC to report on emissions of SF₆, Capiel has developed a comprehensive Inventory Methodology for SF₆ in switchgear, which covers all sorts of use of SF₆ in the Electrical Sector, from the moment of acquiring the SF₆ till the End of Life of the equipment.

It defines the principle of Chain Management, ensuring that the total chain of use of SF₆ is covered, from production of SF₆, via application in switchgear, the operation in the electrical network, its use and maintenance, to the End of Life of the switchgear and the return/destruction of the SF₆.

Inventory Methodology

Chain Management



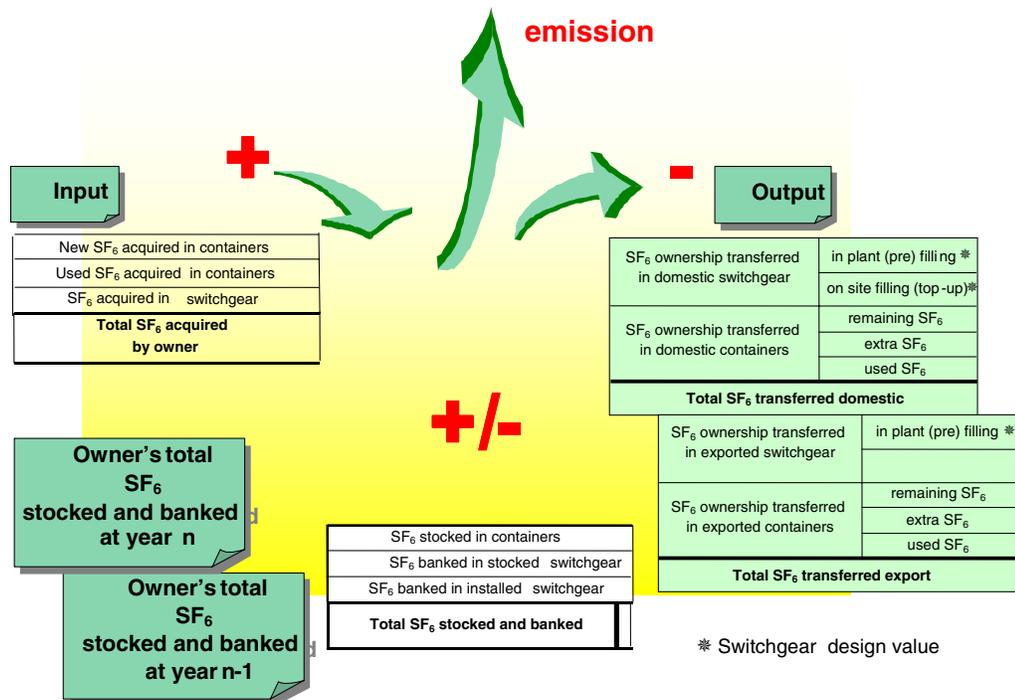
It defines as well the principles of „Ownership“ and „Transfer of Ownership“ to ensure a clear responsibility in any stage of the process of handling SF₆.

The Inventory Methodology is based on a Mass-Balance Approach, as given by IPCC Tier 3b /5/, comparing the input and the output of SF₆ on a calendar year basis. In fact it is the only practical way to determine emissions with a reasonable precision.

Being implemented on a geographical basis, consolidation of information collected from entities identified inside a given country will provide the total emission from the country with no distortion due to international trade.

The principle is shown on the flow diagram.

$$\text{SF}_6 \text{ emission} = \text{input} - \text{output} + \Delta \text{ stock}$$



As part of the Inventory Methodology, a spreadsheet has been developed, enabling an entity to determine its emission in a given year by filling in a number of main data. (see appendix 1)

Presently Capiel is in the process of final testing of the Inventory Methodology and its spreadsheet, and expects to be able to make it available for use by concerned and interested parties, also outside Europe, early 2001.

5 European Union ECCP

With the objective to identify and develop elements of an EU Climate Change Strategy necessary for implementation of the Kyoto Protocol, the European Union has launched the European Climate Change Program (ECCP).

The program basically concentrates on:

- Improvement of inventories and emission data
- Developing measures for emission reductions
- Developing policies to ensure that reductions will be achieved.

To ensure a broad involvement of parties as well as speeding up the process of discussing and decision-making, parties involved in the program are:

- European Commission
- Member States
- Industries, from producers to users of substances.
- (E)NGO's

The topic of reduction of SF₆ emission related to switchgear is addressed in WG-5 Industry, Fluorinated Gases. Capiel and Eurelectric are participating in this WG-5.

The program was launched in the summer of 2000, and it is scheduled to have a comprehensive set of agreed policies and measures ready in spring 2001.

During the meetings Capiel and Eurelectric have jointly presented a set of measures.

measure	manufacturer	user
Permanent improvements in switchgear design for minimal leakage and simplified handling in service as well as at End of Life	Y	
Reduction of emission during manufacture	Y	
Improved filling procedures on site	Y	Y
Better monitoring in service (for larger equipment)		Y
Use of "sealed-for-life" techniques for in particular smaller equipment	Y	Y
Target older existing equipment with known leakage problem for repair/replacement		Y
Improved maintenance procedures including RCM		Y
Improved end-of-life recovery and recycling	Y	Y

Furthermore preferred policy instruments have been presented.

- Inventory on the basis of Mass-balance Methodology, allowing emissions to be estimated for smaller equipments, in particular Sealed for Life.
- Use of voluntary agreements (VA's), flexible to take account of:
 - o Technology Mix in Equipment (GIS, AIS, Sealed for Life)
 - o Manufacturer-User Mix in the Country (Presence of manufacturer and/or SF₆ Switchgear in a country)
 - o Percentage of exported technology and equipment (Is manufacturer output for domestic or export and/or licensed to others)

These will be included in the program and form the basis of the proposals for the final report.

Keeping in mind the prevailing differences of technology as well as manufacturer-user mix, and furthermore the differences in the Kyoto basket in the Member States, the decision on implementation is at Member States.

6 Further Reduction Potential

Analysing the total chain of use and handling SF₆, it can be seen that (potentially) SF₆ is emitted resulting from unnecessary actions. In particular the present practice to fill new switchgear on site

only with SF₆ which meets the requirements of IEC 60376 for new gas, implicates that SF₆ remaining in containers or otherwise is not applied and basically has to be returned to the producer of the SF₆ or the manufacturer of the switchgear. For a number of reasons this is rather impractical, and consequently should be avoided.

The following actions and measures will help to further reduce the emission of ~~SF₆~~-SF₆:

- Avoid unnecessary transport of SF₆
- Promote the concept of recycling and re-use of SF₆ on site /6, 7/
- Ensure re-use of SF₆ in the relevant standards:
 - o IEC 60480, presently under revision, stating that SF₆ acc. this standard is suitable for first filling of new switchgear.
 - o IEC's 60056, 60298, 60517, 60694 etc. to be revised enabling the use of new SF₆ acc. IEC 60376 as well as recycled gas acc. IEC 60480 for first filling of switchgear.
- Promote the use of appropriate handling equipment, ensuring low emissions and re-use of the SF₆
- Promote where feasible setting up of SF₆ handling/storage ventures, country or organisation wise.

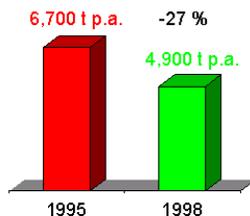
7 Conclusion

Taking into account the positive environmental impact of SF₆ (smaller equipment and safer working operations), the negative environmental effects are clearly turned to a positive balance compared with alternative technical solutions for sustainable power supply, especially since the present contribution of SF₆ from high-voltage switchgear in the EU to non-natural global warming effect is negligible. International recommendations and regulations to limit the losses exist and have to be respected. The implementation of the identified actions will avoid increases from 1995 emission levels, and in fact ensure a reduction of the emission.

Indeed the evaluation of recent atmospheric measurements indicate a reversed trend in emissions of SF₆ into the atmosphere /8/. The annual emissions of SF₆ have declined from peak values of 6,700 tons in 1995 (figure of 6,200 tons originally quoted /3/, corrected by Maiss & Brenninkmeijer, related to concentrations of SF₆ measured in the Northern Hemisphere) to around 4,900 tons in 1998. This is a reduction by 27% due to growing awareness of the climatic relevance of SF₆ resulting in a reduction of substitutable open and semi-open applications and improved handling procedures in case of closed and non-substitutable applications.

Atmospheric measurements: Emission Reduction

Atmospheric measurements (Northern Hemisphere) show reversed trend in SF₆ emission



Reasons:

- Reduction of substitutable open and semi-open applications
- Emission is better controlled by the electrical industry
- Improved handling procedures in case of closed and non-substitutable applications

8 References

- /1/ Federation of Electric Power Companies Japan; Japan Electrical manufacturers' Association; Asahi Glass Co. Ltd.; Kanto Denka Kogyo Co. Ltd.: "Partnership Activities

- for SF₆ Gas Emission Reduction from Gas Insulated Electrical Equipment in Japan." IPCC/TEAP Joint Expert Meeting, Petten, The Netherlands, 26-28 May 1999
- /2/ CAPIEL: "Joint UNIPEDE/CAPIEL statement on switchgear and the greenhouse effect." CAPIEL, Paris, June 1998
 - /3/ Maiss, M.; Brenninkmeijer, C.: "Atmospheric SF₆, trends, sources and prospects." Environmental Science & Technology, 1998, 32, pp 3077-3086
 - /4/ U.S. EPA: "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1998. " April 15, 2000
 - /5/ IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. September 2000
 - /6/ IEC: "High-voltage switchgear and controlgear - Use and handling of sulphur hexafluoride (SF₆) in high-voltage switchgear and controlgear." IEC 61634, Techn. Report, 1995
 - /7/ CIGRE TF 23.10.01: "SF₆ recycling guide. Re-use of SF₆ gas in electrical power equipment and final disposal." Electra No. 173, Aug. 1997, pp 43-71
 - /8/ Maiss, M.; Brenninkmeijer, C.: "A reversed trend in emissions of SF₆ into the atmosphere?" 2nd Int. Symp. on Non-CO₂ Greenhouse Gases (NCGG-2), Noordwijkerhout, The Netherlands, September 8-10, 1999

Monitoring methodology of SF6 emission

Manufacturer x, User y

	End of year	n-1	n
new SF6 stocked in containers	1a		
used SF6 stocked in containers	1b		
total SF6 stocked in containers, actual figure	1 Act		
total SF6 stocked in containers, calculated	$1 = 1a+1b \text{ or } 1Act$	0	0
SF6 banked in stocked switchgear, not yet installed	2a		
SF6 banked in stocked switchgear, retired from installed	2b		
SF6 banked in installed switchgear*	2c		0
total SF6 banked in switchgear, actual figure	2 Act		
total SF6 banked in switchgear, calculated	$2 = 2a+2b+2c \text{ or } 2Act$	0	0
Total quantity Q of SF6 stocked and banked at owner	Q = 1+2	0	0
change in new SF6 stocked in container	$3a = 1a_n - 1a_{n-1}$		0
change in used SF6 stocked in container	$3b = 1b_n - 1b_{n-1}$		0
change in total SF6 stocked in containers, calculated	$3 = 3a+3b \text{ or } 1Act_n - 1Act_{n-1}$		0
change in SF6 banked in stocked switchgear, not yet installed	$4a = 2a_n - 2a_{n-1}$		0
change in SF6 banked in stocked switchgear, retired from installed	$4b = 2b_n - 2b_{n-1}$		0
change in SF6 banked in installed switchgear*	$4c = 2c_n - 2c_{n-1}$		0
change in total SF6 banked in switchgear, calculated	$4 = 4a+4b+4c \text{ or } 2Act_n - 2Act_{n-1}$		0
Change C in stocked and banked SF6	C = 3+4		0
New SF6 acquired in containers	5a		
Used SF6 acquired in containers	5b		
SF6 acquired in new switchgear	5c		
Used SF6 acquired inside retired equipment	5d		
Total SF6 acquired A by owner	A = 5a+5b+5c+5d		0
Total SF6 U used by owner	U = A - C		0
SF6 ownership transferred in new switchgear, domestic	in plant (pre)filling*	6a	
	on site filling (top-up)*	6b	
SF6 transferred in used switchgear, domestic		7	
SF6 ownership transferred in containers, domestic	remaining SF6	8a	
	extra SF6	8b	
	used SF6	8c	
Total SF6 transferred, domestic T_{dom}, actual figure	T_{dom} Act		
Total SF6 transferred, domestic T_{dom}, calculated	T_{dom} = T_{dom} Act or 6a+6b+7+8a+8b+8c		0
SF6 ownership transferred in new switchgear, exported	in plant (pre)filling*	9	
		10	
SF6 ownership transferred in containers, exported	remaining SF6	11a	
	extra SF6	11b	
	used SF6	11c	
Total SF6 transferred, exported T_{exp}, actual figure	T_{exp} Act		
Total SF6 transferred, exported T_{exp}, calculated	T_{exp} = T_{exp} Act or 9+10+11a+11b+11c		0
Total SF6 ownership transferred	T_{tot} = T_{dom} + T_{exp}		0
Total SF6 emitted by owner in the owner's country	E = U - T_{tot}		0

* Switchgear* : design value

Grey cells shall be filled directly. In their absence the White cells shall be filled, which then have priority over the Grey cells
Yellow, Blue and Purple cells are calculated by the system