# Protocol
# 2F8: $SF_6$ HIGH-VOLTAGE POWER INDUSTRY

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|---|---|
| IPCC Category: | 2F8 Other |
| NFR Code: | n.a. |
| NOSE Code: | n.a. |
| NACE Code | 261, 27, 3313,3314, 3323, 3324 and 35 |

## Foreword
Under the Kyoto Protocol, the Netherlands is required to set up and maintain a national system to monitor its greenhouse gas emissions. One of the elements of this system is a transparent and verifiable description of the methods and processes used in this monitoring system. These methods must meet international guideline criteria, which have been defined by the United Nations (UN) and the European Union (EU).

The Netherlands meets the aforementioned requirement, for example, by defining a series of Monitoring Protocols, which describe the methods and work processes used to determine greenhouse gas emissions and the amounts of carbon sinks available. Protocols have been written for about 40 greenhouse gas sources or sinks. This document describes the protocol for one of these sources or sinks.

The protocols have been compiled in close collaboration with experts from various sectors of society in the Netherlands, particularly experts from the Emissions Registration (ER). The ER is a collaborative group that includes institutions such as CBS, WUR, RIVM and PBL. Until 31 December 2009 this was coordinated by PBL (Planbureau for the Leefomgeving, or the Netherlands Environmental Assessment Agency), but on 1 January 2010 this coordination task was taken over by RIVM (the Netherlands institute for public health and the environment). Other institutions that have contributed to the protocols include NL Agency; Ministry of Agriculture, Nature and Food Quality; and the Ministry of VROM (Housing, Spatial Planning and the Environment).

## 1 Scope and significance of emission sources/activities

### 1.1 Scope and definition
This protocol describes the method used to determine $SF_6$ emissions during the production, installation and demolition phases of medium- and high-voltage capacity circuit breakers (insulation and arc extinguishers), including the testing of installations by independent laboratories. This concerns SBI (industry) codes 261, 27, 3313,3314, 3323, 3324 and 35.

$SF_6$ emissions within the Netherlands as a result of all $SF_6$ usage are reported as a single emissions figure, under the CRF (common reporting format) category 2F8. $SF_6$ emissions by the high-voltage power sector, production of semiconductors, double glazing and electromicroscopes are all aggregated into a single figure and reported under the CRF category 2F8 ‘Other’.

The monitoring of $SF_6$ emissions by the high-voltage power sector, the production of double glazing, semiconductors and electromicroscopes are covered by separate protocols. The contribution by the remaining emission sources (e.g. production and use of particle accelerators) does not appear to be substantial: < 0.2 ton $SF_6$/year (DHV, 2000), and is therefore not included when determining the total $SF_6$ emissions.

*Using $SF_6$*
$SF_6$ is used in high-voltage and medium-voltage installations as insulation and/or circuit breaker/arc extinguisher. The gas in the installation is used to prevent voltage arcs between the various electricity potentials. Although air is a fairly good insulator, voltage arcs can still be created if the distance is too short and potential differences too high. If $SF_6$ is used (under pressure) then the chance of voltage arcs and short-circuit leakage is considerably reduced. $SF_6$ can also be used as a so-called ‘extinguisher gas’ for overvoltage protection installations.

*High-voltage vs medium-voltage installations*
High-voltage installations refer to units in excess of 36 kV, while medium-voltage refers to those less than 36 kV. Compared to high-voltage installations (hundreds of kilos of $SF_6$), medium-voltage installations use much smaller quantities of $SF_6$ (only a few kilos). High-voltage installations are used by electricity generation companies, electricity network managers and several large corporations with their own electricity facilities (including Netherlands Railways). The major companies account for around 5% of the total consumption at high-voltage power plants. The number of Dutch users is therefore limited. However, the number of users with medium-voltage installations is greater, as large corporations also use this type of system.

*Emissions*
The aforementioned types of installations can emit $SF_6$ during the production, installation, usage and demolition phases. Since almost all medium-voltage installations are ‘sealed for life’ (a trend that began around halfway through the 1980s), emissions during the usage phase are practically zero.

When manufacturing high-voltage components, products are tested in a real production environment. During this test phase, which takes place during production as well as ‘on site’, the medium-voltage and high-voltage components are filled with $SF_6$ under working pressure. The components are then emptied until they reach a pressure of 0.05 bar. The remainder is thus released.

*Scope*
- Up to around 2003, the Netherlands had only one manufacturer of high-voltage installations. This manufacturer focused primarily on the international market.
- The Netherlands has only one manufacturer of medium-voltage equipment, and this company does not use $SF_6$ in its installations. Various distributors representing foreign manufacturers also operate in the Netherlands, and these companies sell installations that contain $SF_6$.
- Most of the (large) users of medium-voltage and high-voltage circuit breakers, the network managers and electricity generation companies (i.e. around 90%) are members of EnergieNed, the Federation of Energy Companies in the Netherlands. In addition, there are also a limited number of industrial users of high-voltage equipment in the Netherlands.

The Netherlands also has one international test laboratory for power switches, where high-voltage and medium-voltage installations are tested, with or without $SF_6$ as insulation and/or arc extinguishers.

## 1.2 Significance and influences

### *1.2.1 Contribution to total national emissions*
The total emissions of $SF_6$ as reported under sector 2F8 (other) contribute less than 0.5% to the total annual greenhouse gas emissions from the Netherlands.

**Aggregated figures due to confidentiality aspects**
$SF_6$ emissions as a result of using $SF_6$ in the high-voltage power industry, production of semi-conductors, double glazing and electromicroscopes are all aggregated into a single figure and reported under CRF category 2F8 'Other' (UNFCCC, 2004). This is due to the confidentiality of the data. Production data by the (former) Netherlands high-voltage manufacturer, the test laboratory for high-voltage installations, the semiconductor and electromicroscope manufacturers could otherwise be deduced directly from the emissions figures, activity data and implied emission figures under subcategories 6, 7 and 8 of the main 2F group.

### *1.2.2 Developments that infuence emissions*
At European level, new legislation is being prepared to regulate the use of F-gases. This includes an obligation to prevent and minimise leakage of fluor-based greenhouse gases, an obligation to recover fluor-based greenhouse gases from high-voltage installations for recycling, regeneration or destruction, plus an obligation for Member States to create programmes that include education and certification of personnel involved in the recovery, recycling, regeneration or destruction of fluor-based greenhouse gases. This new EU directive is expected to come into effect at the beginning of 2006, and is expected to result in reduced $SF_6$ emissions by the high-voltage power sector. Emission factors will probably need to be revised after 2006.

# 2 Method, emission factors and activity data

## 2.1 Calculation method
Since 2008 (for emissions year 2006) the method of determining $SF_6$ emissions by the high-voltage power sector is based on the annual input and output of $SF_6$ (Van der Stoep and Verhaart, 2007). This occurs as follows:

*Calculation of $SF_6$ emissions from the high-voltage power sector*

*$SF_6$ emissions = [C – (B - A) – D] * 100/95 kg*
*+ emissions from testing installations (6% of use[1]).*

*Where:*
- *A: stock at t-1 (start of measurement period)*
- *B: stock at t (end of measurement period)*
- *C: input t (during measurement period)*
- *D: output t (during measurement period)*
- Factor 100/95: This incremental factor is used to determine the total emissions, including those by several large industrial users (approx. 5% of total emissions).

Emissions for the intervening years (2000-2005) have been recalculated via interpolation, using the new 2006 emission figures, as well as those from 1999 (see also Section 4.4.1).

[1] According to initial estimates by KEMA the emission percentage for servicing and testing equipment is between 4% and 6%. The figure is currently set at 6%.

*Comparison with IPCC method*
The aforementioned method for determining the $SF_6$ emissions by the high-voltage power sector corresponds to the tier 3b method, the Manufacturer and utility-level mass-balance method, as described in the Good Practice Guidance (IPCC GPG, 2001, §3.5.1).
However, the method used for the Netherlands situation is slightly different, because it also includes the $SF_6$ emissions from large industrial users (approx. 5% of the total) and from testing installations in an independent laboratory.

### 2.2 Emission factors

The following country-specific emission factors are used:

- The production emission amounts to 6% of the purchase volume (CAPIEL, 2001). [5]
- According to KEMA's initial estimate, the emission percentage for servicing and testing equipment amounts to between 4 and 6%. For the time being, the value of 6% is used.

### 2.3 Activity data

*Manufacturing installations*
Corporate information regarding $SF_6$ power:
- Amount of $SF_6$ purchased each year for production purposes.
- Amount exported in installations sold to other countries.

The above information was registered until around 2003. This was a flow of confidential information used for external reviews that, under the UNFCCC, could be accessed via the ER's work package leader.

## 3 Working processes

*Process for estimating (t-1)*
If preliminary figures are required at any point, the following process is used to estimate the figure for t-1. The preliminary data for the task force are calculated by extrapolating them from the previous years' figures, based on prognoses for the developments in the most important activity data (taken from CBS (Statistics Netherlands) or other statistical sources).

| INPUT | PROCESS | OUTPUT | BY WHOM |
|---|---|---|---|
| Preliminary data work package leader (t-1) | Include t-1 data in ER database | ER-db with (t-1) data | Work package leader |
| | | | |
| ER-db with (t-1) data | Check emission figures: compare with previous years (trend), modify if required and document everything | ER-db (t-1) with any modified figures | Task force |

*Process for final determination of (t-2)*
The final emission figures (as described in this protocol) are calculated using the following process.

| INPUT | PROCESS | OUTPUT | BY WHOM |
|---|---|---|---|
| - Annual emissions electricity network managers and electricity generation companies (available via EnergieNed).<br>- Annual use of $SF_6$ for testing installations (available via KEMA) | Check increased/decreased emissions and usage figures for testing:<br>- Compare with previous years<br>- Look at the trend<br><br>If unsubstantiated deviations found, contact one or both suppliers<br>→ if required, modify emissions and/or usage figures for testing and document fully | Approved emission and usage figure for testing | Work package leader |
| - Approved emissions and usage figure for testing.<br>- Most recent Emission Factors (EFs), leakage percentages etc. from studies / literature (both national and international) | Enter into (EXCEL) model 'Calculating F-gas emissions'<br><br>This includes the incrementation and emission definition for testing the installations. | Detailed and aggregated emissions (=Final data Work package leader (t-2)) | Work package leader |
| | | | |
| Final data Work package leader (t-2) | Include (t-2) data in ER database | ER-db with (t-2) data | Work package leader |
| | | | |
| ER-db with (t-2) data | Check, and trend analysis of air emissions: explain deviations or modify figures | Final defined emission figures (t-2) | Task forces and PBL experts |

Large industrial corporations with their own high-voltage installations do not report via their respective MJVs (annual environmental reports) and MJAs (long-term agreements).

# 4 Uncertainty and quality

## 4.1 Estimating uncertainties

A Tier-1 uncertainty analysis is implemented every year before the NIR is submitted by the ER, based on the greenhouse gas inventory and in compliance with IPCC guidelines. The assumptions used and the results thereof are described in a background report to the NIR. In addition to this, where included in the QA/QC programme for the relevant period, extra analyses are implemented regularly in specific situations, which include any updating of the Tier-2 uncertainty analyses.

The Tier-2 uncertainty assessment was last updated in 2006. This assessment showed that a Tier-1 uncertainty assessment is sufficiently reliable and that Tier-2 uncertainty assessments need only be implemented at periodic intervals of around 5 years, unless a major change in an important source is sufficient to require earlier reassessment.

- Source-specific uncertainty

The uncertainty estimate $_{total}$ concerns the root of the sum of uncertainty in the data sources used ($AD_{onz}$) in the square and the uncertainty of the emission factor ($EF_{onz}$) in the square.

The extent of the total uncertainty is here primarily determined by the greatest AD or EF uncertainty.

$$\text{Uncertainty estimate}_{\text{total}} = \sqrt{EF_{onz.}{}^2 + AD_{onz.}{}^2}$$

The uncertainty estimates concerning the data sources (AD) and emission factors (EF) used, and the total uncertainty estimate, are listed in the following table.

| IPCC | Category | Gas | $AD_{onz.}$ | $EF_{onz.}$ | Uncertainty estimates $_{tot}$ |
|---|---|---|---|---|---|
| 2F | SF6 emissions from SF6 use | SF6 | 50 | 25 | 56 |

The uncertainty in $SF_6$ emissions from $SF_6$ consumption was estimated to be about 56%. The uncertainty in the activity data for the $SF_6$ sources was estimated at 50%. For the $SF_6$ emission factor, the uncertainties was estimated at 25%. All of these figures were based on expert judgements [Olivier et al, 2009].

## 4.2 Quality assurance and quality control (QA/QC)

The ER work package leaders check that:

1. the basic data are well documented and adopted (check for typing errors, use of the correct unit sizes and correct conversion);
2. the calculations have been implemented correctly;
3. assumptions are consistent, also whether specific parameters (e.g. activity data) are used consistently;
4. complete and consistent data sets have been supplied.

Any actions that result from these checks are noted on an ‘action list’. Before defining the data, supervisors check whether the relevant actions on this list, plus the QC checks, have all been completed. Defining the data is carried out by the WEM (working group on emissions monitoring), and confirmed in writing via an e-mail from the institute representatives to the ER project leader at PBL.

The work package leaders fill out a new documentation sheet when adding new data. For reasons of efficiency a minimum level has been set for obligatory documentation, i.e. 5% changes at target group level, and 0.5% at levels concerning the national total. These documentation sheets form part of the trend analysis, as well as the eventual definition of the data set.

The ER work package leaders communicate by e-mail regarding these QC checks, results and actions. They send a printed copy to the ER secretary, who keeps a logbook and compiles these e-mails into an ‘action list’. This shows explicitly that the required checks and corrections have been carried out.

## 4.3 Verification

In order to check the quality of the emission figures for the sources in this protocol, general QA/QC procedures have been followed that are in line with the IPCC guidelines. These are described further in the QAQC programme used by the National System, and the annual working plans published by the ER.

- Sector-specific QC

No additional specific verification procedures are implemented for the sources defined in this protocol.

## 4.4 Possibilities for improvement compared to the current calculation method

### *4.4.1 History*

*Method for determining emissions up to 1998*

Up to 1998 the total $SF_6$ emissions in the Netherlands were determined via an estimate, under the system used by the Netherlands Emissions Registration (ER) based on the formula: usage = emissions (= potential emissions). This is based on usage figures in 1990[2] and the economic growth of the relevant sectors from 1990 onwards. In 1995 and 1998 the emissions (based on this calculation method) amounted to 1.5 Mton $CO_2$ eq.

*Method for determining emissions from 1998 through 2005*

From 1998 to 2005, $SF_6$ emissions by the high-voltage power sector were based on usage figures for $SF_6$ as well as $SF_6$ losses incurred during various process stages (= actual emissions). This occurred as follows:

***$SF_6$ emissions***
*=*
*+ production-emission (6% of purchase volume)*
*+ emissions from installations in NL (6% of increase)*
*+ emissions through leakage and handling on-site in NL (4% of total banked)*
*+ emissions through discarded installations in NL (0.2 ton – dismantled installation in Hoogeveen)*
*+ emissions when testing installations (6% of use[3]).*

The total banked includes the $SF_6$ amounts in high-voltage installations at electricity generation companies, network managers and at several large industrial corporations with their own power facilities, as well as in medium-voltage installations. The total banked amount was only inventoried once – in 1999. From 1999 onwards the annual increase in the total amount was estimated based on economic developments and extrapolation.
The aforementioned method for determining $SF_6$ emissions by the high-voltage power sector complies with the tier 2 method (lifecycle emission factor approach) described in the IPCC Good Practice Guidance (IPCC, GPG, 2001, §3.5.1). However, the method used for the Netherlands situation is slightly different, because it also includes the $SF_6$ emissions resulting from testing installations in an independent laboratory.

### *4.4.2 Future*

When determining $SF_6$ emissions in the Netherlands it is important to regularly adjust these emission figures (every three or five years). To date this has not yet been regulated.

[2] The $SF_6$ usage in 1990 is estimated by Matthijssen and Kroeze (1996), based on a study by Annema (1989), at 1.4 Mton $CO_2$-eq. (approxiately 59 ton $SF_6$).
[3] According to an initial estimate by KEMA, the emission percentage for servicing and testing equipment is 4-6%. Current assumptions are based on 6%.

# 5 Remaining aspects

## 5.1 Point source criteria
Not applicable

## 5.2 Substance profiles
Not applicable

## 5.3 Regionalisation
Not applicable

## 5.4 Time-based variations in source strength
Not applicable

# 6 References and additional information

## 6.1 References

- Capiel, 2001: *Methodology to quantify emission of SF6 for SF6 switchgear production and use.*
- DHV, 2000: *Identificatie van onbekende bronnen van overige broeikasgassen (Identification of unknown sources of other greenhouse gas emissions).*
- IPCC, 1997: Revised 1996 IPCC Guidelines for National Greenhouse Gas Emission Inventories, Three volumes: Reference Manual, Reporting Guidelines and Workbook. IPCC/OECD/IEA. IPCC WG1 Technical Support Unit, Hadley Centre, Meteorological Office, Bracknell, UK
- IPCC, 2001: Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, IPCC-TSU NGGIP, Japan
- Olivier J.G.J., L.J. Brandes and R.A.B. te Molder, 2009 (in print) Uncertainty in the Netherlands’ greenhouse gas emissions inventory: Estimate of annual and trend uncertainty for Dutch sources of greenhouse gas emissions using the IPCC Tier 1 approach, PBL-Report 500080013, Bilthoven
- UNFCCC, 2004: *Guidelines for the preparation of national communications by Parties included in Annex I to the convention, Part I: UNFCCC reporting guidelines on annual inventories*, UNFCCC/SBSTA/2004/8, 3 September 2004.
- Stoep, J.W. van der, H.F.A. Verhaart, 2007. SF6–emissie energiebedrijven. Kema in opdracht van SenterNovem. Arnhem, september 2007


## 6.2 Additional information
Not applicable