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Sulphur Hexafluoride (SF_6)

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Sulphur Hexafluoride (SF_6) – an Environmental Accounting Primer

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What is Sulphur Hexafluoride?

Sulphur Hexafluoride (SF_6) is a colourless, odourless gas used in a small number of specialised applications. Although not toxic, SF_6 is an asphyxiant and poses a health hazard in enclosed environments. With a relatively high molecular weight (146), SF_6 is around five times heavier than air and tends to accumulate in confined low-lying areas.

SF_6 is highly persistent, with an atmospheric lifetime of 650 to 3,200 years. It has been identified as one of the most potent greenhouse gases, with a global warming potential (GWP) estimated at 23,900 times that of carbon dioxide (CO_2) when measured over 100 years[1]. Thus, 1 kg of SF_6 is currently considered to have the equivalent global warming potential of 23,900 kg CO_2 over a 100 year period.

At the United Nations Framework Convention on Climate Change meeting in November-December 2011 in Durban, South Africa, countries agreed to adopt updated GWPs including new greenhouse gases published in the Intergovernmental Panel on Climate Change's (IPCC) 2007 Fourth Assessment Report (AR4). The new AR4 factor for SF_6 is 22,800 and will apply from 2015 onwards (reporting emissions for the 2013/14 inventory year, i.e. from 1 July 2013).

There are very few natural sinks for SF_6, so virtually all human-made SF_6 emissions accumulate in the atmosphere. Global average concentration of SF_6 has doubled since the 1990s. Part of this trend is reflected in recent recordings, e.g. the atmospheric concentration of SF_6 was 4.5 parts per trillion (ppt) in the year 2000 and 7.5 ppt in 2012 (2).

Overview of SF_6 in Australia

In Australia, about 10 to 20 tonnes of SF_6 are imported annually. The gas is used principally in the electricity transmission and distribution industries as a gaseous dielectric (insulator) for insulation and arc suppression in medium-voltage and high-voltage equipment. Lower volumes of SF_6 are used in a number of other applications, including:

- Semiconductor manufacture - plasma etching of silicon wafers;
- Magnesium smelting – exclusion of oxygen;
- Gas dispersion modelling and leak testing;
- Specialised medical procedures (e.g. some forms of eye surgery), and

[1] This factor is originally from the IPCC's Second Assessment Report (AR2), as cited in the Fourth Assessment Report (1).

- Novel applications such as monitoring exhaled methane in dairy cows (3) (4).

For example, about 36 kg of SF_6 was used for dispersion modelling in Melbourne's underground railway stations to estimate gas flow from a hypothetical terrorist attack using a gaseous threat agent (5). Under NGER, none of this (860 t CO_2-e) was accounted for. Similar testing is also understood to have occurred in Perth.

SF_6 is used by all the major electrical switchgear manufacturers in devices such as ring main units (RMUs), reclosers and some transformers. It is also used in substation installations in commercial and other buildings where space restrictions dictate the use of compact switchgear (vacuum or air-insulated gear can't match SF_6 equipment for compactness). Vacuum circuit breakers are sometimes used instead of SF_6 breakers, particularly at distribution level voltages, but SF_6 breakers are likely to continue being used in the foreseeable future.

Common situations that may cause the escape of SF_6 to the environment include:

- failure of seals
- escapes during commissioning of switchgear and equipment
- during operational checking of gas pressure on site
- sampling and transporting for off-site gas analysis
- recovery, reclaiming and refilling
- recovery and reclaiming at the end of the life of the equipment.

In Australia, the Energy Networks Association (ENA) has produced the 'ENA Industry Guideline for SF_6 Management' (6) that aims to minimise SF_6 emissions in the energy network industry through implementation of best practice processes. This document has been used as the basis of Methods 2 and 3 in the NGER Measurement Determination (sections 4.103 and 4.104).

SF_6 and the Carbon Price Mechanism

Under the Australian Government's Clean Energy Future Plan, a levy with an equivalent carbon price applies to the importation or manufacture of a range of synthetic greenhouse gases, including SF_6, under the Ozone Protection and Synthetic Greenhouse Gas Management Act 1989.

Importers of SF_6 (and other synthetic greenhouse gases) are, from 1 July 2012, required to have a Controlled Substances license or an Ozone Depleting Substance/Synthetic Greenhouse Gas Equipment licence (previously called a Pre-Charged Equipment licence).

Licence holders are required to pay a quarterly import levy consisting of a prescribed rate component of $165 per metric tonne of gas imported and a carbon charge component based on an equivalent carbon price. This is calculated by multiplying the GWP of the gas (23,900 for SF_6) by the quantity imported and by the equivalent carbon price current at the time of import. The following table shows the equivalent carbon price per metric tonne of SF_6 for the next three years:

Year	**Price per tonne CO_2** (as per Carbon Price Mechanism)	**Price per tonne SF_6** [\$165 + (\$/tCO_2 x 23,900)]
2012/13	\$23.00	\$549,865
2013/14	\$24.15	\$577,350
2014/15	\$25.40	\$607,225

Licensees may claim a refund of the carbon charge component if they export the synthetic greenhouse gas or equipment within 12 months of its import, or if they on-sell to a business which exports the gas or equipment within 12 months of its import.

Under the Clean Energy Future plan, the equivalent carbon price for SF_6 penalises industries that do not actively release SF_6. By imposing the equivalent carbon price at the point of import, all users are subjected to the increased cost. Thus, the cost of around \$550,000 per tonne of SF_6 imported has to be paid regardless of whether the tonne of SF_6 is contained or released into the atmosphere. In contrast, other forms of GHG emissions are taxed on the basis of actual emission to atmosphere.

Furthermore, under NGER and the Clean Energy Future plan, a substantial quantity of SF_6 in lost an industrial accident from other than gas insulated switchgear or circuit breakers would not have to be accounted for (e.g. S4.102(4) of NGER (Measurement) Determination 2008).

The application of a carbon charge based on an equivalent carbon price to synthetic greenhouse gases, including SF_6, aims to encourage users to better contain these gases in equipment to stop leakage, improve their recycling rates, switch to alternative gases that have lower or zero global warming potential, or where possible to change to alternative technologies where SF_6 is not used (7). Thus, once SF_6 users realise that replacement of the gas beyond their stockpile imported prior to mid-2012 will cost around \$550,000 per tonne (\$550 per kilogram), they will become more careful about minimising losses.

However, the SF_6 emission reduction incentive may fail under some circumstances. For example, there is little incentive in the electricity supply industry to reduce SF_6 emissions if the supplier has already paid around \$550,000 per tonne of SF_6, has passed on the cost and doesn't have to account for SF6 emissions at a later date.

How can fugitive emissions of SF_6 be avoided or minimised?

Restricting fugitive emissions is best attained through high manufacturing standards. Most manufacturers quote values of 0.1% *per annum* leakage for modern equipment. Typically, gas insulated switchgear (GIS) is either "closed" or "sealed for life". Closed switchgear can be topped up with more SF_6 in the event of leakage, while sealed for life switchgear requires no maintenance or topping up over its service life. It is in the interest of distribution network operators to retain SF_6 in switchgear to the greatest extent possible, because leakage can result in equipment failure and network outages.

The amount of SF_6 leakage from electrical switchgear depends on the filling quantity and the rating and design of the equipment. It is estimated that for high-voltage (HV) switchgear, annual leakage ranges from about 0.1% - 0.5% by weight. The upper limit of this range (0.5%) is the maximum acceptable leakage rate according to IEC 62271-203. For sealed for life medium-voltage (MV) equipment, a leakage rate of less than 0.1 % per year is common (8). For example, a 2 kg SF_6 charge in an RMU would yield a calculated loss of 2 g per year. In practice, however, this would not usually be realised as an annual loss because there is a range of values for the quantity / pressure of SF_6 within which the switchgear will function correctly and top up may not occur until the gas charge approaches the lower acceptable limit.

Technicians responsible for handling, installing and maintaining equipment containing SF_6 should be trained in specialised procedures. They must comply with all legislative and regulatory requirements, including relevant codes of practice, work health and safety legislation and with competition and consumer legislation.

From an environmental accounting point of view, it is important to use a consistent approach in reporting SF_6 and to clearly state assumptions and methods used to calculate SF_6 emissions. Currently, considerable variation exists in the ways in which major SF_6 users in Australia report their annual SF_6 emissions.

For example, in the electricity distribution network sector, Energex reported losses of 37 kg of SF_6 in 2009-10 (9), and 12 kg of SF_6 losses in the year ending June 2011 (10). Ausgrid reported a loss of around 154 kg SF_6 in 2010-11 (11), although this was calculated using **NGER Method 1** that assumed 0.5% per year leakage. Endeavour Energy reported a loss of around 85 kg SF_6 in 2010-11 (12), but it is unclear in the report how this figure was derived. SP AusNet cited a figure of 1.15% for SF_6 loss as a proportion of their total 2010/11 Scope 1 GHG emissions, without providing an actual figure for the total (13).

SF_6 accounting under NGER

For the 2010/11 reporting period, **NGER Method 1** assumes that 0.5% by mass of the total SF_6 used in electrical switchgear will leak per year (this figure is based upon the maximum acceptable SF_6 annual leakage specified in IEC 62271-203). This Method 1 assumption has been revised to leakage of 0.89% by mass SF_6 for the 2011/12 reporting year (see Column 4 of table in S4.102(4) of NGER (Measurement) Determination 2008, as amended).

For **NGER Method 2**, pressure gauges supplied with some GIS equipment should not be relied upon for quantifying SF_6 leakage, because they are generally crude indicators (some gauges are of a go - no go type). Cylinders should be weighed to quantify the amount of SF_6 used in top up, so that other losses (e.g. from line purging) can also be accounted for.

Requirements for entering SF_6 and other GHG data under NGER have changed over the course of the reporting scheme. In the 2008-2009 reporting year, it was necessary to multiply the stock of each GHG by the relevant Global Warming Potential (GWP) factor prior to entry into OSCAR. However, for the 2009-10 reporting year onward, the GWP should **not** be applied to the stock figure prior to entry into OSCAR. Only the raw stock figure (e.g. kg of SF_6) should be entered; OSCAR will automatically apply the GWP to calculate CO_2-e units.

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