THE GNCS FACTSHEETS

Mitigating SF_6 Emissions

Sulfur hexafluoride (SF_6) is a powerful greenhouse gas due to its highly effective absorption of infrared radiation as well as its extremely long atmospheric life span.[1] Therefore, despite its small atmospheric concentration relative to carbon dioxide (CO_2), SF_6 contributes a disproportionately large share to anthropogenic radiative forcing.[2] Although emissions of SF_6 have stayed relatively constant since 1998, their long atmospheric lifetimes (between 1,000 and 5,000 years) and the resulting accumulation of SF_6 in the atmosphere means that the gas's contribution to radiative forcing has increased 36% over the same period.[3]

Emissions from the major sources of SF_6 production (magnesium die casting and the manufacture and use of electrical equipment) are expected to nearly double between now and 2030.[4] Growth in global SF_6 emissions will be driven primarily by growth in developing nations through 2020: SF_6 emissions from electrical equipment will rise with the growth of electricity infrastructure as demand for electricity rises.[5] In magnesium production, China represents the largest share of the international market, driven by low-cost exports and closures of plants in the US, Canada, Norway and Japan.[6]

Sources of SF_6

The most significant sources of SF_6 emissions are from the manufacture, operation and disposal of electrical equipment (27 million tons of CO_2 equivalent ($MtCO_2e$) in 2000,[7] representing 80% of global sales of SF_6)[8] and magnesium die casting (9 $MtCO_2e$ in 2000).[9] In addition, smaller amounts of SF_6 are used in semiconductor production, as a tracer gas, for sound proofing in windows, in aluminum production and as an alternative to air in filling car tires.[10]

An inert gas, SF_6 is used as an insulator for electrical equipment, to protect it from overloads and short circuit currents, as well as to connect and disconnect networks.[11] In this context, SF_6 is emitted primarily through leaks over the lifetime of the equipment (approximately one third of emissions);[12] during maintenance, when the equipment must be opened for repairs and SF_6 escapes; or when the equipment is decommissioned (maintenance and decommissioning together represent approximately two thirds of emissions).[13] Although SF_6 emissions from electrical equipment decreased significantly between 1990 and 2000 due to the high price of SF_6 and technical improvements,[14] emissions increased by 55% between 2000 and 2003 due to increased sales and higher rates of retirement for electrical equipment.[15]

Magnesium production, an energy intensive process, has increased worldwide due to high demand for the lightweight metal, especially in the transportation industry.[16] In magnesium die casting, SF_6 is used as a cover gas to protect the molten metal from oxidation or ignition.[17] It is emitted due to its function as a cover gas: SF_6 emissions in the magnesium industry are therefore roughly equal to the industry's consumption of the gas.[18]

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[1] EPA. (2006). *Global Mitigation of Non-CO_2 Greenhouse Gases*. Washington D.C.: US Environmental Protection Agency. p. I 4.
[2] The major fluorinated greenhouse gases (HFCs, PFCs and SF_6) comprised only 1% of global emissions in 2000. Ibid. p.12; and Schaefer, D., Godwin, D. and Harnisch, J. (2006). "Estimating Future Emissions and Potential Reductions of HFCs, PFCs & SF6." *The Energy Journal*. p. 64.
[3] IPCC AR4 WG1. (2007). "Changes in Atmospheric Constituents and in Radiative Forcing." Ch.2 in *Climate Change 2007: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, UK: CUP. p. 141 & 145.
[4] IPCC AR4 WG3. (2007). "Industry." Ch. 7 in *Climate Change 2007: Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* CUP. p. 454, 471.
[5] EPA (2006), p. IV 188.
[6] *Ibid.* p. IV 205.
[7] IPCC AR4 WG3 (2007), p. 471.
[8] EPA (2006), p. IV 187.
[9] IPCC AR4 WG3 (2007), p. 464.
[10] EPA (2006), p. I 5; Schaefer, Godwin and Harnisch (2006), p. 64; and Harnisch, J. and Schwarz, W. (2003). *Cost and the impact on emissions of potential regulatory framework for reducing emissions of hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride.* European Commission, Directorate of the Environment. p. 12.
[11] Wartmann, S. and Harnisch, J. (2005). *Reductions of SF6 Emissions from High and Medium Voltage Electrical Equipment in Europe.* Nuerenberg, Germany: Ecofys. p. 5.
[12] EPA (2006), p. IV 190.
[13] *Ibid.*
[14] Wartmann and Harnisch (2005), p. 25.
[15] EPA (2006), p. IV 188.
[16] IPCC AR4 WG3 (2007), p. 464.
[17] Harnisch and Schwarz (2003), p. 24.
[18] Harnisch and Schwarz (2003), p. 24; and EPA (2006), p. IV 205.

Abatement Options

Electrical Equipment: SF_6 emissions resulting from leaks in electrical equipment can be addressed through leak detection and repair (LDAR) and, for larger leaks, refurbishment. LDAR measures have the potential to reduce approximately 30% of emissions from equipment with uncontrolled emissions.[19] Emissions during maintenance can be addressed by switching to equipment that requires less frequent maintenance (e.g. state-of-the-art sealed pressure systems, which generally do not require maintenance during their 40 year lifetimes)[20] and through training of staff, best practices for gas handling and awareness-raising (i.e. staff education and labeling programs). These contributed to a decline in SF_6 emissions in Europe and Japan from 1995 to 2003, despite a 60% increase in production in that period.[21]

Theoretically, 100% of the SF_6 emitted during the decommissioning of electrical equipment could be recovered, purified and reused, presenting a significant mitigation opportunity.[22] Practical recovery rates are closer to 80% due to increasing marginal recovery costs.[23] In addition, a comprehensive decommissioning infrastructure is required for large-scale gas recovery, including highly-trained staff and the legal considerations around international waste transportation.[24]

Magnesium production: Technical improvements and more efficient operational practices, which resulted from rising SF_6 prices between 1995 and 2000, mean the amount of SF_6 used per ton of magnesium produced has already reached an effective limit.[25] Therefore, further emission reductions must be achieved through the use of an alternative cover gas.[26] SF_6 replaced sulfur dioxide (SO_2) as a cover gas in magnesium production in the 1970s.[27] Although the toxicity of SO_2 increases handling difficulties, it is commercially available, can be used in a wide range of magnesium casting processes, and poses few additional problems or costs compared to SF_6.[28] HFC-134a is a problematic alternative, since it is also a powerful greenhouse gas. It may, however, be preferable to SF_6 due to its smaller atmospheric lifetime and potency, as well as its more thorough decomposition.[29]

Mitigation Costs

Multiple analyses find SF_6 recovery or replacement measures to be low cost and even cost saving. The US Environmental Protection Agency (EPA), for example, assesses the recovery and recycling of SF_6 as a cost saving measure, since recycling of the gas reduces the facility's consumption and therefore its operating costs.[30] The EU Environment Directorate finds that SF_6 replacement with SO_2 in magnesium die casting is "economic" for both new and retrofitted plants (retrofitting is more expensive than installing a new SO_2 plant).[31]

Current Policies and Standards

The EPA has launched a number of voluntary partnerships with industries that emit SF_6, which has resulted in approximately 11.5 $MtCO_2e$ of emissions avoided between 1990 and 2005. The EPA Partnership for Electric Power Systems represents close to half the US industry, and recorded a 45.6% decrease in SF_6 emissions between 1999 and 2006, primarily through LDAR, equipment upgrades and refurbishment, gas recovery and recycling, and employee training.[32] The EPA partnership with the International Magnesium Association (IMA), which represents around half of global magnesium production, was launched in 1999 and resulted in a 40% reduction in emissions intensity between 1999 and 2002, primarily through the optimization of equipment design and improved gas management.[33] The IMA has a stated goal of eliminating SF_6 emissions, which will necessitate the use of alternative cover gases.[34] World Semiconductor Council (WSC) members, which represent 90% of production, achieved a 10% greenhouse gas reduction on 1995 levels by sharing information and best practices.[35]

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Further resources are available at **www.theGNCS.org**

19 EPA (2006), p. IV 193.
20 Wartmann and Harnisch (2005), p. 7.
21 IPCC AR4 WG3 (2007), p. 471.
22 EPA (2006), p. IV 192.
23 *Ibid.*
24 Wartmann and Harnisch (2005), p. 26.
25 EPA (2006), p. IV 205.
26 Harnisch and Schwarz (2003), p. 26.
27 *Ibid.* p. 24.
28 *Ibid.* p. 30.
29 *Ibid.* p. 75.
30 EPA (2006), p. IV 192.
31 Harnisch and Schwarz (2003), p. 30.
32 EPA (2007), p. 2, 4. See: http://www.epa.gov/electricpower-sf6.
33 See: http://www.epa.gov/highgwp1/magnesium-sf6/basic.html.
34 IPCC AR4 WG3 (2007), p. 464.
35 See: http://www.semiconductorcouncil.org/activities.