Danish Ministry of the Environment
Environmental Protection Agency

The Greenhouse gases: HFCs, PFCs and SF6

Danish consumption and emissions, 2010

Environmental project no. 1402, 2012

Title:

and SF6

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Preface

On behalf of the Danish Environmental Protection Agency (Danish EPA), the consultant PlanMiljø ApS carried out the emission calculation of Danish emission of F-gases, 2010. The emission calculation is provided in continuation of previous years emission calculations /27/ and references herein.

The F-gas emission calculation and reporting is assessed by Danish EPA and National Environmental Research Institute, Denmark (NERI) and the consultant. Further the draft report is send to central stakeholders for comments and general information.

The assessment group consisted of:

- Mikkel Aamand Sørensen, Danish EPA
- Frank Jensen, Danish EPA
- Leif Hoffman, Danish National Environmental Research Institute (NERI), University of Aarhus
- Tomas Sander Poulsen, PlanMiljø ApS
- Torkil Høft, KMO
- Sven-Erik Jepsen, Confederation of Danish Industries (DI)

The objective of this project was to determine the Danish consumption and actual emissions of F-gases (HFCs, PFCs, and SF_6) for 2010.

The emission calculation is partly conducted to fulfil Denmarks international obligations to provide data and information on F-gas emissions, and partly to follow the Danish trend in consumption and emissions of HFCs, PFCs, and SF_6. Examples of reporting of Danish emissions is given in reference /18, 19, 21, 23, 24, 26/, and most recently, in reference /28/.

Greenhouse gases cause an increase in the ability of the atmosphere to retain surplus heat radiated from the earth. Consequently the temperature of the earth's surface and lower atmosphere is rising and this leads to climate changes. There are several ozone-depleting substances that also have a strong greenhouse effect. These substances are regulated under the Montreal Protocol.

The potential effect of different greenhouse gases varies from substance to substance. This potential is expressed by a GWP value (Global Warming Potential). The so-called F-gases (HFCs, PFCs and SF_6) that do not have an ozone-depleting effect, but which have high GWP values are regulated by the Kyoto Protocol under the United Nation Climate Change Convention.

The Danish EPA has published a booklet on the ozone layer and the greenhouse effect /5/, and the Danish EPA has also published a report on substituting the greenhouse gases HFCs, PFCs and SF_6 /10/.

1 Summary

1.1 Danish consumption and emission of F-gases

1.1.1 Import

HFCs
In 2010, the total import (minus re-export) of pure HFCs and HFC blends was estimated to 352.7 tonnes. Compared to 2009, where total was 363.2 tonnes, the total import of HFC's has decreased with 10.3 tonnes.

The 2010 import of HFC-134a decreased slightly with 7.5 tonnes compared to
2009 with a total import of 167.8 tonnes (MDI included). The consumption of refrigerants is lower for household fridge & freezers and commercial refrigerants in 2010 compared to 2009 whereas the consumption of refrigerants for mobile A/C systems is higher.

The import of HFC-404A is reduced with 3.3 tonnes compared with 2009. The total consumption is 103.6 tonnes in 2010. The reduction is mainly caused by reduction of consumption in commercial refrigeration system.

Import of HFC-407c has declined with 7 tonnes to 42.4 tonnes in 2010. HFC-407C is a substitute refrigerant for HCFC-22 in refrigerators and refrigerant in heat pumps. Over the last decade there has been an overall increase in import of HFC-407c but the trend in consumption has not been stabile.

The overall picture of the import and consumption in 2010 is a small reduction of the main refrigerants (HFC-134a, HFC-404A, HFC-407c).

SF_6
The overall consumption of SF_6 in 2010 was approx. 3.8 tonnes. This is a decrease compared with 2009. Consumption of SF_6 derives from two areas:

- used for power switches in high-voltage power systems
- laboratories/optics fibre production

PFCs
The Danish consumption of PFCs (per fluoropropane) in 2010 was 1 tonnes. The PFC consumption in 2010 derives only from one source; optics fibre production

1.1.2 Emission

The GWP-weighted actual emissions of HFCs, PFCs, and SF_6 in 2010 were 854.0 thousand tonnes CO_2 equivalents. The emission has increased compared to 2009, where the corresponding emissions were 848.4 thousand tonnes CO_2 equivalents as reported in /27/.

The total emission in 2010 has increased for both HFCs, and SF_6 but decreased a bit for the PFCs compared to 2009.

The increase in emissions for HFCs is in particular due to emissions of HFC-134A.

In Table 1.1, consumption, actual emissions and stock in products are summarised.

Table 1.1 Consumption, actual emissions, stock, actual emission and GWP contribution from greenhouse F-gases 2010, tonnes.

Source	Substance	Consumption and imports, DK, tonnes	Stock, tonnes	Actual emis-sions, tonnes	GWP contribution, CO2 eqv. tonnes	GWP contribution in total, CO2 eqv. tonnes
Refrigerants for commercial stationary refrigerators and A/C systems	HFC-134a	80,6	809,1	82,7	107 557	
	HFC-404A	96,0	931,3	107,5	350 385	
	HFC-401A	0,0	6,0	0,7		
	HFC-402A	0,0	13,1	1,5	2 487	
	HFC-407c	42,4	438,5	45,0	68 566	
	HFC-507	9,1	64,7	6,3	19 631	
	Other HFC-er	21,0	132,1	14,4	24 783	
	PFC	0,0	9,0	1,0	7 015	
	All substances					**580 423**
Household fridges/freezers Refrigerants	HFC-134a	6,8	807,2	8,5	11 034	
	HFC-404A	1,5	85,3	1,0	3 180	
Insulationfoam	HFC-134	0,0	757,5	66,7	86 689	
	HFC-152	0,0	0,0	0,0		
	All substances					**100 902**
Refrigerants for mobile A/C systems	HFC-134a	67,3	0,0	67,3	87 490	**87 490**
Refrigerated vans and lorries	HFC-134a	0,5	3,9	0,7	933	
	HFC-404A	6,1	31,9	5,7	18 428	
	HFC-402A	0,0	0,6	0,1	200	
	All substances					**19 561**
Other PUR foam and system foam	HFC-134a/245	0,2	4,8	0,0		
Aerosol sprays etc.	HFC-134a	5,2	0,0	5,6	7 300	**7 300**
Thermostates	HFC-152a	15,0	72,7	4,3	601	**601**
MDI	HFC-134a	7,2	0,0	7,2	9 407	**9 407**
System foam	HFC-134a		0,0	0,0		
	HFC-152a		0,0	0,0		
	HFC-365		0,0	0,0		
Liquid cleaners	PFC	0,0	0,0	0,0		
Fibre optics	PFC-14	0,4	0,0	0,4	2 340	
	PFC-318	0,5	0,0	0,5	3 915	
	HFC-23	0,4	0,0	0,4	4 212	
	All substances					**10 467**
Double glazing	SF6	0,0	34,8	0,4	8 391	**8 391**
High-voltage power switches	SF6	3,2	85,5	0,6	14 192	**14 192**
Laboratories	SF6	0,6	0,0	0,6	15 296	**15 296**

Total	HFC-er		4158,8	352,7	802 881	
	PFC-er		9,0	1,0	13 270	
	SF6		123,1	1,6	37 879	
GWP contribution	Total				**854 030**	

In Figure 1.1, the relative contributions of HFCs, PFCs, and SF_6 to the total emission in CO_2-equivalents are shown for application areas for 2010.

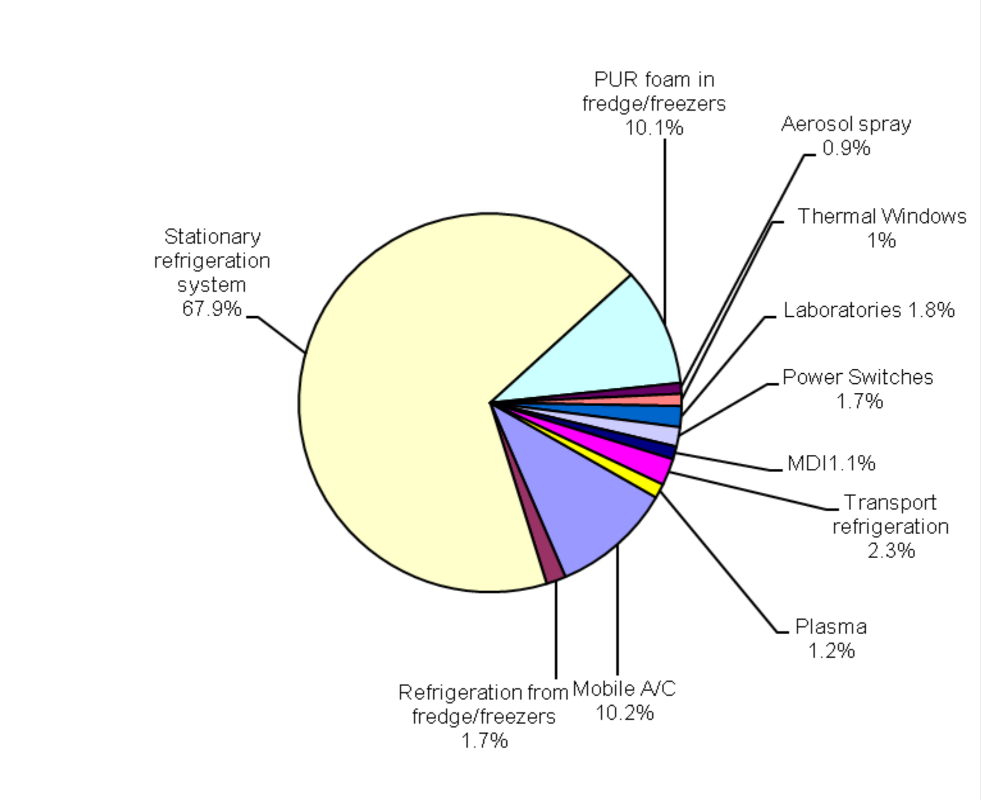

Figure 1.1 Relative distribution of GWP emissions by application area, 2010

The figure shows that emissions from refrigerants used in commercial stationary refrigerators account for the outmost largest GWP contribution. This source covers 67.9 per cent of the total actual emission of F-gases in 2010. The major contribution is from HFC-404A.

The second-largest GWP contribution, accounting for 10.1 per cent, is emission from release of HFC-134a stock in insulating foam in fridges and freezers.

Emissions of HFC-134a from mobile A/C contribute with 10.2 per cent and emissions of HFC-134a and HFC-404A from transport refrigeration contribute with 2.3 per cent of the total GWP contribution.

The three sources of SF_6 emissions in 2010 were power switches, double glazing windows and laboratories/fibre optics. These account for 4.5 per cent of the total GWP contribution.

HFC’s contribution is estimated to comprise 94 per cent of the overall GWP contribution in 2010, Emissions of SF_6 comprise 4.5 per cent and emissions of PFC contribute with 1.6 per cent of the total emission.

HFCs

Actual emissions from HFCs have been calculated to 802 881 tonnes CO_2 equivalents. In 2009, emissions were 797 573 tonnes CO_2 equivalents, refer /27/. It is a small decrease of approx. 5 310 tonnes CO_2 equivalents.

SF_6
Actual emissions have been calculated at 1.6 tonnes, equivalent to a GWP contribution of 37 879 tonnes CO_2 equivalents. In 2009, emissions were 36 686 tonnes CO_2 equivalents, refer /27/.

PFCs
The emission of PFCs origins from PFCs in production of fibre optics and stock emission from commercial refrigeration containing HFC-413A. The total GWP-weighted PFC emission is 13 270 tonnes CO_2 equivalents.

1.1.3 Trends in total GWP contribution from F-gases

Figure 1.3 shows the trend in Danish GWP contributions from HFCs, PFCs, and SF_6 for 1992-2010. The differences from the present calculations of the total GWP value compared with earlier calculation methods are illustrated in the figure.

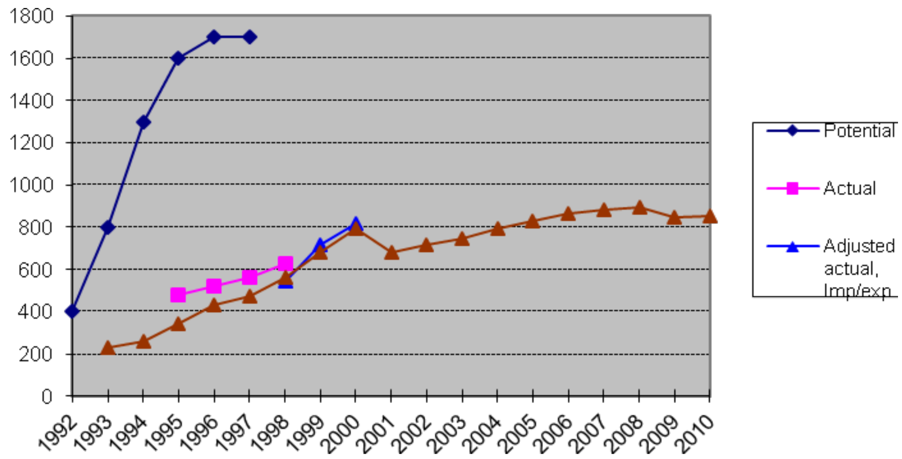

Figure 1.3 Trends in GWP-weighted potential, actual and adjusted actual emissions 1992-2010, 1.000 tonnes CO_2 equivalents.

The figure shows that the GWP emission has increased since 2001 and the first year with a decrease is 2009 and in 2010 the emission increased slightly again. The highest level of actual emissions is from 2008. The trend for following years shows a clear decrease of approximately 50 000 tonnes CO_2 equivalents pr. year.

The development in the GWP contribution 1992-2010 can also be seen in Table 1.2 below. In 2008 emission calculations from MDI is added, which contain an increasing amounts of HFC-134a as blowing agent.

Table 1.2 Total GWP-contribution from HFCs, PFCs, SF_6, 1992-2010 determined according to the four different methods of calculation applied during this period, 1 000 tonnes CO_2 equivalents,

	Potential	Actual	Actual, adjusted imp/exp.	New actual, adjusted imp/exp.	New Actual adjusted imp/exp. Including new source
1992	400				
1993	800			195	
1994	1300			257	
1995	1600	480		326	
1996	1700	520		397	
1997	1700	560		401	
1998		625	577	479	
1999			700	581	
2000			818	783	
2001				702	
2002				723	
2003				750	
2004				803	
2005				836	
2006				873	
2007				894	
2008				886	895
2009					849
2010					854

The table 1.3 below shows the time series 1993-2010 and the 2011-2020 projections of F-gases as GWP contributions.

The emission projections are determined by starting with a ‘steady state’ consumption using 2010 as the reference year and the cut-off dates for the phasing-out of specific substances, cf. the Statutory Order regulating certain industrial greenhouse gases.

The calculated GWP contribution expresses actual emissions, adjusted for imports and exports (the latest basis of calculation).

Table 1.3 Total GWP-emission from HFCs, PFCs, SF_6, 1994-2020, 1 000 tonnes CO_2 equivalents

	HFC-134a	HFC-152a	HFC-404a	HFC-401a	HFC-402	HFC-407c	HFC-507a	HFC-23	Other HFCs	PFC-er	SF6	Total pr year
1993	89,7	4,2	0,0	0,0	0,0	0,0	0,0		0,0	0,0	101,2	195,1
1994	126,6	6,4	1,4	0,0	0,1	0,0	0,0		0,0	0,1	122,1	256,6
1995	194,9	6,1	15,3	0,0	1,2	0,0	0,0		0,4	0,5	107,3	325,6
1996	264,1	4,5	54,2	0,0	3,7	0,0	0,0		2,9	1,7	61,0	391,9
1997	222,6	2,1	85,7	0,0	6,6	0,3	0,4		6,0	4,1	73,1	400,9
1998	270,8	1,3	117,8	0,1	7,6	2,5	2,9		8,1	9,1	59,4	479,5
1999	291,5	5,3	176,8	0,1	8,7	5,4	5,7		10,2	12,5	64,9	581,1
2000	320,7	2,3	239,6	0,1	9,5	11,0	8,9		14,1	17,9	58,8	682,8
2001	341,4	1,8	236,8	0,1	9,0	16,6	14,3		29,4	22,1	30,0	701,6
2002	355,0	1,8	256,5	0,1	8,0	22,2	14,2		17,5	22,2	25,0	722,6
2003	334,4	0,2	290,0	0,1	7,0	33,8	17,0		17,2	19,3	31,4	750,4
2004	353,2	0,8	312,7	0,0	6,1	45,3	18,2		17,8	15,9	32,7	802,7
2005	344,3	0,2	358,1	0,0	5,2	55,3	19,4		18,4	13,9	21,3	836,3
2006	343,2	0,4	375,4	0,0	4,5	59,4	19,2		20,0	15,7	35,6	873,3
2007	346,9	0,4	391,6	0,0	3,9	63,7	19,4		22,8	15,4	29,9	893,9
2008	342,9	0,5	393,0	0,0	3,4	65,7	20,5	1,4	23,9	12,8	31,2	895,3
2009	293,0	0,5	385,5	0,0	3,0	68,4	19,3	2,8	25,1	14,2	37,7	849,4
2010	310,4	0,6	372,0	0,0	2,7	68,6	19,6	4,2	24,8	13,3	37,9	854,0
2011	292,5	0,7	330,2	0,0	2,4	67,9	20,4	4,2	23,1	12,5	70,9	824,7
2012	253,6	0,7	299,3	0,0	2,1	67,4	20,3	4,2	19,7	11,9	117,0	796,4
2013	231,7	0,8	274,3	0,0	1,9	64,8	17,8	4,2	17,3	11,3	127,0	751,2
2014	180,8	0,9	242,1	0,0	1,7	62,0	14,9	4,2	15,4	10,8	139,5	672,2
2015	151,5	0,9	200,7	0,0	1,5	55,9	12,2	4,2	11,2	10,3	124,8	573,3
2016	117,0	1,0	159,5	0,0	1,4	49,6	5,5	4,2	8,3	9,9	97,1	453,5
2017	74,7	1,0	130,8	0,0	1,2	40,4	6,3	4,2	6,3	9,5	82,2	356,7
2018	59,2	1,1	84,6	0,0	1,1	25,0	3,1	4,2	6,2	9,2	82,6	276,2
2019	55,6	1,1	61,7	0,0	1,0	10,9	1,9	4,2	5,0	8,9	81,7	232,1
2020	43,5	1,2	17,6	0,0	0,9	5,0	0,0	4,2	0,1	8,7	61,2	142,4
I alt	**6.606**	**49**	**5.863**	**1**	**105**	**967**	**301**		**371**	**314**	**1.944**	**16.520,9**

2 Methodology

The emission calculation is made in accordance with the IPCC guidelines (Intergovernmental Panel on Climate Change) /4/, and following the method applied in previous years calculations.

The methodology includes calculation of the actual emissions of HFCs, PFCs, and SF_6. In this calculation of actual emissions, the release from stock of greenhouse gases in equipment and in products has been taken into account, and adjustments have been made for imports and exports of the greenhouse gases in products. Appendix 4 describes the specific emission factors, etc.

2.1 Scope and definition

The emission calculation of the actual emissions of HFCs, PFCs and SF_6 has over years become increasingly more comprehensive and accurate along with the development of internationally approved guidelines (IPCC Guidelines) and guidance (IPCC Good Practice Guidance) and the provision of increasingly detailed data.

The evaluation of the actual emissions includes quantification and calculation of any imports and exports of HFCs, PFCs, and SF_6 in products, and it includes substances in stock. This is in accordance with the latest and most accurate method of calculation (Tier 2) among the options provided for in the IPCC Guidelines /4/.

Estimation of Consumption and emissions

The calculation of consumption, emissions and stock were carried out on the basis of information from five sources:

- Importers, agency enterprises, wholesalers, and suppliers
- Consuming enterprises, and trade and industry associations
- Danish Environmental Protection Agency
- KMO, the Danish Refrigeration Installers' Environmental Scheme
- Previous evaluations of HFCs, PFCs and SF_6 /2, 11, 13, 16, 25/.

Basis information for the present emission calculation is collected through questionnaire surveys combined with follow up telephone interviews.

The result of the project is primarily based on the information received from enterprise and importer respondents and information from KMO and Danish EPA is used as a supplement to verify parts of the collected data.

The information collected from importers and suppliers is compared with information from consumer enterprises in order to monitor any discrepancies between purchase and sales information and to identify application of the use of substances. In some cases, the use of individual substances was estimated on the basis of two sources, since the majority of the consuming enterprises were known. In cases where not all enterprise end-users had specified the application area for substances, the consumption of individual substances was estimated on the basis of the information provided by importers, suppliers, and any trade and industry-related associations, such as KMO.

There may be inconsistencies between the information provided by suppliers and enterprise end-users. This is partly due to imports from other EU countries, changes in inventories of substances, or a lack of correlation between the quantities sold and the quantities consumed. It is also partly due to a certain amount of uncertainty in the method of calculation used by enterprises. However, sales and consumption information has been harmonised.

The estimated average degree of uncertainty in the report's consumption figures (quantities sold and bought) is about 10-15 per cent, and slightly greater for data regarding application areas. The degree of uncertainty in the calculation of actual emissions is estimated at 20-25 per cent, depending on import/export information for the specific products.

The calculation of F-gas emission is based on a calculation of actual emissions.

Actual emissions are emissions in the relevant year, accounting for the time lapse between consumption and emissions. Actual emissions include Danish emissions from production, from products during their lifetimes, and from the disposal of products. Actual emissions for the specific areas of application are determined on basis of the following approaches:

Tier 2 “Top-down” analysis
In the Tier 2 Top-down analysis, emissions are determined on the basis of information on consumption in the various areas of application and calculated or estimated emissions in the area of application (emission factors).

Tier 2 “Bottom-up” analysis.
In the Bottom-up analysis, the estimated emissions for a specific application area are based on information from producers using substances in production and in products; information on imports and exports of products; information on the technological developments within the application areas; information on the average amount of greenhouse gases contained in products; and information on the lifetime of products and actual emissions during their use and disposal.

Tier 2 bottom-up analysis were carried out within selected areas over a number of years. The analysis quantified the stock and, in some cases, Danish emission factors. Detailed analysis were carried out for commercial refrigerators, mobile A/C systems, fridges, freezers, and SF_6 power switches. Analysis were evaluated in separate reports /2, 11, 16/.

Bottom-up comprises:

- Screening of the market for products in which greenhouse gases are used.
- Defining the average content of greenhouse gases per product unit.
- Defining the lifetime and the disposal emissions of products.
- Identifying technological characteristics and trends of significance for emissions of greenhouse gases.

- Calculating imports and exports on the basis of defined key figures, Statistics Denmark's foreign trade statistics, and information from relevant industries.

Results from this analysis have been expanded in the present evaluation of actual emissions.

As far as possible, the consumption and emissions of greenhouse gases have been evaluated individually, even though consumption of certain HFCs has been very limited. This was done to ensure transparency and consistency in time in the calculation of the sum of HFCs as their GWP value. However, it was necessary to operate with a category for "Other HFCs", as not all importers and suppliers have detailed records of sales of individual substances.

Uncertainty varies from substance to substance. Uncertainty is highest for HFC-134a due to its widespread application in products imported and exported. The largest uncertainty in the analysis of substances by application areas is assessed to concern the breakdown of consumption of HFC-404A and HFC-134a between commercial stationary refrigerators and mobile A/C systems. This breakdown is significant for the short-term (about 5 years) emissions calculations, but will balance in the long term. This is because the breakdown is only significant for the rate at which emissions are released.

Appendix 4 shows an overview of all application areas included with descriptions of the bases of calculation.

In Appendix 1, the table shows the F-gases covered by the Kyoto Protocol under the Climate Change Convention, including their chemical formulas and GWP values (Global Warming Potential).

2.2 Explanation of terminology

The following terms and abbreviations are used throughout this report:

- Enterprise end-user: A producer that uses greenhouse F-gases in connection with production processes in the enterprise.

- Emission factor: The factor used in the calculation of emissions from a product or a production process.

- Consumption: Consumption includes the quantities of substances reported in Denmark in the year in question via imports from wholesalers and information from Danish producers.

- Importer: Enterprises in Denmark that sell the relevant substances on the Danish market.

- KMO: The Danish Refrigeration Installers' Environmental Scheme

- Stock: The amount of substance contained in equipment and products in use in Denmark.

3 F-gas import and consumption

3.1 Import of substances

An overall picture of the trends in imports of greenhouse gases is given in Table 3.1, based on information from importers for the years 1992, 1994-2010.

3.1.1 HFCs

HFCs were imported by 11 enterprises in 2010. Five of them imports for resale and four of the importers is consumers importing substances directly from another EU country and use the imported substances in production.

The total import (minus re-export) of pure HFCs and HFC blends is estimated to 353.7 tonnes. Compared to 2009, where the estimation of total import was 363.2 tonnes, the import has a small decrease of 9.5 tonnes. The most significant trend in the development is the 14.7 tonnes decrease in bulk import of HFC-134a (excl. MDI).

The bulk import of HFC-134a is 160.6 tonnes and has decreased with 14.7 tonnes compared to 2009. The consumption of HFC-134a in commercial refrigeration has decreased considerably compared to 2009 and the consumption level is now at the same level as 2007. Thus the consumption has decreased for both commercial and household refrigeration the consumption for mobile A/C has increased considerably from 43.8 in 2009 to 67.3 in 2010. In 2010, the import of HFCs in products is associated to an import of HFC-134a in medical doze inhalers of 7.2 tonnes. The total import (bulk + products) of HFC-134a is thereafter 167.8 tonnes in 2010.

Import of HFC-404A is decreased with 3.3 tonnes compared to 2009, and the total import in 2010 is 103.6 tonnes. The consumption of HFC 404A in commercial refrigeration system is reduced slightly from approximately 100 to 96 tonnes. While the consumption of HFC-404A refrigerant in transport refrigeration systems and household fridges has had a slight increased to 6.1 tonnes for transport and 1.5 for household.

The third largest HFC import is HFC-407c with an import of 42.4 tonnes in 2010. Compared to 2009, with an import of 49.4 tonnes it is a small decrease of approx. 7 tonnes. HFC-407c is used in heat pumps and is substitute refrigerant for HCFC-22 in commercial refrigeration systems.

The import of HFC-152a was 15 tonnes in 2010. This is a small increase compared to the import in 2009. HFC-152a is used in thermostats.

Summarizing, the import has decreased for, HFC-134a, HFC-404A and HFC-407c. The particular largest decrease is the import of HFC-134a. The only import increases in 2010 were smaller amounts of HFC-152a, HFC-507 and HFC-410A.

3.1.2 Sulphur hexafluoride

Six importers reported having imported and sold 3.8 tonnes of sulphur hexafluoride in 2010. Sulphur hexafluoride was mainly used in power switches, but smaller amounts are used as an agent for plasma erosion in production of micro chips and in laboratories for analysis purposes.

3.1.3 Perfluorinated hydrocarbons

One importer has reported import of PFC-14 (CF_4) of approx. 0.4 tonnes in 2010.
PFC-14 is used in production of optical fibres which are a relatively new consumption area in Denmark. Further there was an import of PFC-318 (c-C_4F_8) of approx. 0.5. The consumption is the same as the 2009 consumption of PFCs.

Like in 2009, there were no import of perfluorpropan $C_3F_{8,}$ in 2010, and it is expected that this refrigerant is fased out of the marked.

Table 3.1 Developments in bulk imports of greenhouse gases, tonnes

Substance	1992	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
HFC-134a	20	524	565	740	700	884	644,6	711,1	472,8	401,6	241,2	306,5	235,4	280,7	160,7	164,5	175,3	160,6
HFC-152a	4	51	47	32	15	14	35,8	16,4	11,1	11,9	3,3	11	5,5	11,6	13	15,0	12,0	15,0
HFC-401A						15	15	9,5	4,1	0	0,2	0	0	0	0	0,0	0,0	0,0
HFC-402A						10	10	4,2	0,8	0	1,7	0	0	0	0	0,0	0,0	0,0
HFC-404A	0	36	119	110	110	146	193,7	193,1	126,2	188,7	145	252,6	162,4	176,4	129,9	114,1	106,9	103,6
HFC-407c						17	40	44,7	40,3	89,1	96,8	101,3	61,6	70,6	50,5	76,8	49,3	42,4
HFC-507						10	10	23,8	2,2	14,4	9,2	10,6	5,4	6,1	11,4	1,8	7,0	9,1
HFC-410A												2,6	3,1	7,7	12,8	16,9	12,1	16,0
HFC-413A												7,2	5		1	0,7	0,0	0,0
HFC-417A												6	1,3	0,9	2,1	0,7	0,0	1,0
Other HFCs[1]	0	1	14	20	65	15	29,2	24,1	18,4	7,5	13	4,4	5,1	4,8	21	8,9	0,6	5,4
All HFCs	24	612	745	902	890	1111	978,3	1027	675,9	713,2	510,4	702,2	484,8	558,8	402,4	399,4	363,2	352,9
SF6	15	21	17	11	13	9	12,1	9	4,7	1,4	2,2	2,3	3,6	4,2	5,4	5,9	4,3	3,8
PFCs	0	0	1,5	3	8		7,9	6,9	3,7	2	0,5	0,3	0,5	0	0,7	68,9	0,9	0,9

1) The category "other" includes HFC-408a, HFC-409a, R422, R424A, R426A, RS24, RS44

Beside the import of substances stated in table 3.1 there is also an import of HFCs for 100% re-export. These amounts are not included in the table. To be mentioned is import and re-export of HFC-365 and HFC-245fa. These HFCs are used in Danish production of PUR system foam (semi manufactured articles). The production is only for export (use of HFC based PUR systems are banned in Denmark). Furthermore the production does not course emissions through the production process. The particular amount is therefore excluded for further calculation of Danish f-gas emissions. The amounts are known by DEPA.

3.2 Consumption by application

The assessment of consumption divided into application areas is estimated on basis of information from importers and producers, and on sales reports to the

Danish Refrigeration Installers' Environmental Scheme (KMO). Table 3.2 shows consumption distributed according to application.

Table 3.2 Consumption of HFC distributed on application areas in 2010, tonnes

	134a	152a	401a	402a	404a	407c	507a	410a	413a	417a	Other HFCs	Total
Insulation foam	0,0											0,0
Foam systems	0,2											0,2
Soft foam	0,0	0										0,0
Other applications	5,2	15,0									1,2	21,4
Household fridges/freezers	6,8				1,5							8,2
Commercial refrigerators	70,6				96,0		9,1	16,0	0,0	1,0	4,2	196,9
Transport refrigeration	0,5				6,1							6,6
Mobile A/C	67,3											67,3
Stationary A/C	10,0					42,4						52,4
Total	**160,56**	**15,0**	**0,0**	**0,0**	**103,56**	**42,4**	**9,08**	**16,0**	**0,0**	**1,0**	**5,4**	**352,9**

1) Bulk import is 160.56 tonnes and including 7.2 tonnes import from MDI in products the total HFC-134a import is 167.8 tonnes

3.2.1 Consumption of HFC refrigerant

The consumption of HFC refrigerants is decreasing. For HFC-134a the consumption is lower than in 2009, and for HFC-404A, we now have the lowest level of consumption since we started this reporting in 1995. In relation to HFC-407c the consumption has decreased again and is now on the same level as in 2007.

The generally low level of refrigerants in commercial refrigeration systems is in particular a consequence of the f-gas regulation where establishment of new HFC installations after 1/1 2007 is banned.

The use of HFCs as refrigerant in commercial refrigeration and stationary A/C systems is covering almost 80 per cent of the total consumption in 2010. The most commonly used refrigerant in commercial refrigeration is still HFC-404A and HFC-134a.

The consumption of HFC-134a as a refrigerant in fridges/freezers was approx. 2.3 per cent of the total consumption in 2010. Most producers has substituted to alternative refrigerants or moved production facilities to other countries.

The consumption of refrigerants in vans and lorries for transport refrigeration covers approx. 2 per cent of the total consumption.

Consumption by application area is based on information from producers and importers and on data from KMO, which receives reports of the sales of substances from refrigerator installers and automobile garages, etc. (only when drawing-off is more than 1 kg).

The consumption of refrigerants for household fridges and freezers is calculated on the basis of information from enterprise end-users.

The consumption of refrigerants in commercial, stationary A/C systems and MAC are estimated using data and information from importers.

The consumption of HFCs in medical doze inhalers is based on product statistics from Danish Medical Agency.

Table 3.3 shows the consumption by weight of refrigerants according to application area.

Table 3.3 Consumption of HFC as refrigerants according to application, 2010.

Substance	Fridges /freezers, t	Commercial refrigerators	Mobile A/C systems, t	vans and trucks, t	Total, t	In per cent
134a	6,8	80,6	67,3	0,5	155,2	46,9
401A	-	-	-	-	0,0	0,0
402A	-	-	-	-	0,0	0,0
404A	1,5	96,0	-	6,1	103,6	31,3
407c	-	42,4	-	-	42,4	12,8
410A		16,0			16,0	4,8
507A	-	9,1	-	-	9,1	2,7
Others	-	5,0	-	-	5,0	1,5
Total	8,2	249,0	67,3	6,6	331,1	-
In percent	2,5	75,2	20,3	2,0	-	100,0

Calculating consumption for refilling mobile A/C (MAC)
The method for calculating the consumption of refrigerant related to MAC is improved in the 2009 and 2010 calculation. The new issue is that it has been possible to identify and collect data from all Danish importers of HFC-134a supplying refrigerants to refilling in mobile A/C systems installed in vehicles. While these importers only operate in the MAC refrigeration market the import data can be isolated to consumption of refrigerants to MAC. Therefore following methodology can be applied corresponding to the Tier 2 top down approach:

- Consumption/Sale from MAC refrigerant importers in year X = Refilled stock = actual emission from MAC in Denmark in year X.

3.2.2 Consumption of HFC as foam blowing agent and as propellant

It is considered that the trend in the recent years with a general reduction of the HFC consumption as a blowing agent, is a direct consequence of a statutory order on phase-out of F-gases, as well the fact that there are competitive alternative technologies available on the market. As regards production of system foam for production, there is a decrease in the recent years in production of system foam for export.

In 2010, the uses of HFCs as propellants in aerosols for specific purposes were about 5.2 tonnes. This estimate is based on DEPA’s grant of exemptions and production. The consumption seems to be stable tending to a decrease.

In 2010, the consumption of HFC 134a in medical doze inhalers was estimated to 7.2 tonnes.

As in previous years, there have been no reports of consumption of HFCs for chemical production, fire extinguishing equipment, or other application areas apart from those mentioned.

3.2.3 Consumption of SF_6

The overall consumption of SF_6 in 2010 was estimated to 3.8 tonnes. Consumption of SF_6 was used for power switches in high-voltage power systems and laboratories. Consumption of SF_6 in production of double glazed thermal windows has been banned since 1. January 2003.

Table 3.5 Consumption of SF_6 by application area, tonnes

Application area	DK consumption, tonnes
Double-glazed windows	-
Power switches in high-voltage plants	3.2
Laboratories and micro chip production (plasma erosion)	0.6
Total	3.8

3.2.4 Consumption of PFCs

The consumption of PFCs (per fluoropropane) is reported to be 0.9 in 2010. The PFC consumption in 2010 derives from optics fibre production

The optics fibre production used in 2010 PFC-14 (0.4 tonnes) and PFC-318 (0.5 tonnes) for technical purposes.

There is no consumption in 2010 of the blend refrigerant.

4 Emission of F-gases

This section reports the actual emissions of the greenhouse F-gases HFCs, PFCs, and SF_6 for 2010. All emissions are calculated as actual emissions according to IPCC's tier 2 methodology. Since 2008 MDI has been included in the report.

The calculation is based on the reports on consumption of these substances analysed by application areas (section 3.2). For relevant product groups, adjustments have been made for imports and exports of the substances in products (see also chapter two for principal description of methodology). The specific emission calculation refers to appendix 4 which shows the particular emission factors, calculation method and assumptions, determination of IPPC Tier method etc., in relation to calculation of emissions from individual substance and application areas /4, 16/.

The total GWP-weighted actual emission of HFCs, PFCs, and SF_6 in 2010 is calculated to 854.0 thousand tonnes CO_2 equivalents. The corresponding emissions in 2009 were approx. 848.4 thousand tonnes CO_2 equivalents. In absolute figures it corresponds to a calculated total increase of approx. 6 thousand tonnes CO_2 equivalents.

The consumption and GWP contribution for HFCs, PFCs, and SF_6 for 2009 and 2010 are shown in the table below.

Table 4.1 Consumption and GWP contribution by substance group, tonnes

Substance group	Consumption 2009, tonnes	Consumption 2010, tonnes	GWP contribution 2009, tonnes	GWP contribution 2010, tonnes
HFCs	363.2	352.9	797 573	802 881
PFCs	0.9	0.9	14 177	13 270
SF_6	4.2	3.8	36 686	37 879
Total			848 435	**854 030**

4.1.1 Emissions of HFCs from refrigerants

As required in the IPCC guidance for calculation of emission of f-gases a distinction is made between:

- Fridges and freezers for household use and retailers etc.
- Commercial refrigeration (in industry and retail) and stationary air conditioning systems
- Mobile air conditioning systems (in cars, trucks, bus, trains etc.)
- Mobile refrigeration systems (in vans and lorries)

Actual emissions from these sources occur in connection with:

- filling of refrigerants (emission is 0.5 percent to 2 per cent of refilled amount depending on application area).
- continual release during the operational lifetime. An assumed average value which account operational leakage including release occurring as a result of

accident and damage (depending on application area, the average yearly emission differ from 10 percent to 33 percent).

Release resulting from disposal of items and equipment in the applications is not calculated as a contribution to the total f-gas emissions in Denmark because Danish legislation ensures that management and treatment of refrigerants prevent uncontrolled emissions. Thus, disposal in Denmark is stated as an activity in the calculations where zero emission occurs and this principal statement are used in order to reduce stock (the quantity of substances contained in a product after end life time).

Appendix 3 shows the specific emission factors used in the calculations.

Commercial refrigeration and stationary A/C systems

Commercial refrigeration, used e.g. in retail, supermarket, restaurants etc. or in industry, and stationary A/C systems, also used by retailers and industry, as well in offices, constitute the largest source of emissions. The most commonly used refrigerants in this product group are HFC-134a, HFC-404A and HFC-407c, where HFC-404A stands for the majority of the emissions in 2009.

In addition, use of the refrigerants HFC-408A, HFC-409A, HFC-410A, and HFC-507 is less common, and HFC-401A and HFC-402A are phased out in Denmark because of the substances contents of ozone depleting substances.

It is not relevant to adjust for imports and exports of HFCs in stationary commercial refrigeration and stationary A/C systems since filling of refrigerants only will take place on site when the units are installed.

Table 4.2 shows the consumption, stock and actual emission for 2009 for the main HFC substances used in Danish commercial refrigeration systems. Emissions for HFCs have been converted to CO_2 equivalents in order to take into account the different GWP values of the substances and emission for 2015 and 2020 in a future scenario is also shown.

Table 4.2 Consumption, stock and actual emissions and GWP contribution from commercial refrigeration 2009; GWP contribution for 2015 and 2020, tonnes

	Substance	Consumption, DK 2010	Stock, 2010	Actual emissions, 2010	GWP-contribution 2010	GWP-contribution 2015	GWP-contribution 2020
Commercial refrigeration and	HFC-134a	80,6	809,1	82,7	107557	50476	574
stationary A/C systems 1)	HFC-404a	96,0	931,3	107,5	350385	179651	348
	HFC-401a	0,0	6,0	0,7	0	5	3
	HFC-402a	0,0	13,1	1,5	2487	1447	855
	HFC-407c	42,4	438,5	45,0	68566	55852	5044
	HFC-507a	9,1	64,7	6,3	19631	12222	0
	other HFC 1)	21,0	132,1	14,4	24783	11173	75
	All				**573408**	**310828**	**6898**

1) The category "Other HFCs" includes HFC-408a, -409a -410A, -413A, -417A (the emission are calculated based on an assumption that average GWP value is similar to HFC-410A).

The projected future scenario takes into account the effect of a statutory order on phasing-out HFCs etc. and the effect of taxes on F-gases. As the tabel indicates the emissions from commercial refrigeration will continue in several years even though there are no installations of new HFC refrigeration systems because of the statutory order which do not allow construction of new installations (larger than 10 kg HFC) after 1. January 2007. In the trend analysis, the total emission from this sector is estimated to more than 310 000 tonnes CO_2 equivalents in year 2015. But after then a significant reduction is expected and in year 2020 most HFC refrigeration systems is considered phased out.

Refrigerators/freezers
Actual emissions from refrigerants in refrigerators and freezers are determined on the basis of consumption adjusted for imports and exports of HFCs. The calculation assumes that the refrigerant is removed and treated upon disposal so that no emission occurs (see appendix 3).

When adjusting for imports and exports, the estimates of imports/exports in Environmental Project no. 523 are used /2/. In this case, exports are assumed to comprise 50 percent of the consumption pr. year. The calculation is made on the basis of Statistics Denmark's foreign trade statistics /3/ of average figures of the amount of HFC-134a in a standard fridge/freezer manufactured in 1999. This figure has not been updated

Table 4.3 below shows actual emissions from refrigerators/freezers in 2010, 2015 and 2020.

Table 4.3 Emissions of refrigerants from refrigerators/freezers 2010, 2015 and 2020, tonnes

	HFC-134a			HFC-404a		
	2010	2015	2020	2010	2015	2020
Consumption	6,8	6,8	6,8	1,5	1,5	1,5
Emissions during production	0,1	0,1	0,1	0,0	0,0	0,0
Export	3,4	3,4	3,4	0,0	0,0	0,0
Stock	807,2	385,8	142,0	85,3	39,4	23,9
Emission from stock	8,4	4,4	1,7	2,6	8,0	3,3
Emisison from destruction	0,0	0,0	0,0	0,0	0,0	0,0
Actual emission	8,5	4,5	1,9	1,0	0,5	0,3
GWP contribution, 1 000 tonnes CO2 equivalents	11,0	5,8	2,4	3,2	1,8	1,0

Total emissions of HFC-134a and HFC-404A refrigerants from refrigerators/freezers in 2010 were estimated to 14 200 tonnes CO_2 equivalents. In the future scenario of actual emissions, it is estimated that the total emission in 2015 will decrease to 7 600 tonnes CO_2 equivalents caused by a decreasing stock.

Mobile A/C
Emissions from mobile A/C systems are mainly due to leakage and accident damage.

Starting from 2009, the refilled and consumed amount of HFC-134a is calculated based on a Tier 2 top-down approach were the importers of HFC-134a for mobile A/C systems are isolated. The consumption of HFC-134a for mobile A/C systems is used solely for refilling. Initial filling is carried out by car manufacturers in the country of production. With the new approach it is possible to reduce uncertainties in determining the actual consumption of refrigerants for refilling in vehicles in Denmark in 2010.

Within the next five years, emission from mobile A/C is assumed to be the application area with the largest emission of HFC-134a in Denmark.

Actual emissions from mobile A/C are stated in the Table 4.4.

Table 4.4 Actual emissions of HFC-134a from mobile A/C, 2010, 2015 and 2020, tonnes.

	2010	2015	2020
Consumption to refilling	67,3	42,3	18,7
Actual emissions	67,3	42,3	18,7
GWP contribution, 1 000 tonnes CO_2 equivalents	87,5	55,0	24,2

Vans and lorries with transport refrigeration system

There are an estimated 5 500-6 000 refrigerator vans and lorries in Denmark /16/. These require an average filling of about 8 kg, equivalent to approx. 46-49 tonnes refrigerants (HFC-134a, HFC-404A or HCFC-22) for the total stock in vans and lorries.

Actual emissions from mobile refrigeration systems in vans and lorries in 2010 are stated in the Table 4.5.

Table 4.5 Calculation parameters and actual emissions of HFC-134a and HFC-404A from vans and lorries with transport refrigeration system for 2010, 2015 and 2020 tonnes.

	HFC-134a			HFC-404a		
	2010	2015	2020	2010	2015	2020
Consumption	0,5	0,5	0,5	6,1	6,1	6,1
Emissions from filling	0,0	0,0	0,0	0,3	0,3	0,3
Contribution to stock	0,5	0,5	0,5	5,8	5,8	5,8
Emissions from Stock	0,7	0,6	0,0	5,3	5,6	4,7
Stock	3,9	3,2	0,0	31,9	33,3	27,1
Actual emissions	0,7	0,6	0,0	5,7	5,9	5,0
GWP contribution, 1 000 tonnes CO2 equivalents	0,9	0,8	0,0	18,4	19,3	16,3

There has been no consumption of HFC-402A for refrigerator vans and lorries since this substance has been banned for use in both new and old installations. But the emission from stock is still about 0.1 tonnes HFC-402A, corresponding to 200 tonnes CO_2 equivalents.

The total actual emission from mobile refrigeration systems in vans and lorries were estimated to 19.5 tonnes CO_2 equivalents in 2010 which is a small increase compared to the 2009 estimate.

4.1.2 Emissions of HFCs from PUR foam products and propellants

Tree calculation principles have been applied in the calculation of emissions of HFCs used in Polyurethan (PUR) foam plastic products, depending on the type of product:

1) Hard PUR foam plastics (closed cell)

2) Soft PUR foam plastics (open cell)

3) Polyether foam (closed cell)

The calculation principles are summerized in table 4.6 below and in appendix four.

	Hard PUR foam	Soft PUR foam	Polyether foam
Release during production, %	10	100	15
Annual loss, %	4.5	-	4.5
Lifetime, years	15	-	1-10

Table 4.6 Emission factors in the calculation of emissions from foam plastic products

Insulation foam

There is no longer production of HFC based hard PUR insulation foam in Denmark. This production has been banned in statutory order since 1. January 2006.

The import of HFC-134a in products with PUR insulation foam, e.g. household fridges and freezers, is considered to be 0 in 2010. This assumption is difficult to verify and no applicable method seems available.

The calculation of actual emissions are therefore only from existing stock of household fridges and freezers.

Actual emissions of HFC-134a from insulating foam are summarised in Table 4.7.

Table 4.7 Calculation parameters and emissions of HFC-134a from insulating foam for 2010, 2015 and 2020, tonnes

	2010	2015	2020
Consumption, HFC 134a	0,0	0,0	0,0
Emission from production	0,0	0,0	0,0
Export	0,0	0,0	0,0
Stock	757,5	159,1	0,2
Emission from stock	66,7	17,9	0,0
Aktuel emission	66,7	17,9	0,0
GWP-contribution, 1000 tonnes CO2-equivalents	86,7	23,2	0,0

In the projection scenario for 2015 and 2020, it is estimated that the stock will be reduced significantly in 2015 as a result of the phase-out of HFC-134a as blowing agent and from 2018 it is estimated that there will be no more actual emissions from this source.

Aerosol sprays

Emission of HFCs from their use as aerosol spray is estimated as 100 per cent of the consumption in the year of application /4/. Emissions from this use occur during consumption after calculation of imports and exports.

Total emission from this areas amounts in 2010 to 5.6 tonnes of HFC-134a corresponding to 7 300 tonnes CO_2 equivalents. Compared with 2009, emission estimates have decreased by approx. 1 200 tonnes CO_2 equivalents.

Medical Doze Inhalers (MDI)
The emission of HFC-134a from medical doze inhalers is estimated as 100 per cent of the consumption in the year of application. Calculation of emission from MDI is based on yearly statistics from Danish Medicines Agency. A survey has determined that HFA (HFC 134a) has been fully introduced in all MDI on the Danish market, since 2007. The average content is 72 mg/pr. doze.

The total emission in 2010 from MDI was 7.2 tonnes of HFC-134a corresponding to 9 400 tonnes CO_2 equivalents. A time-series of the emission of HFC-134a from MDI has been included the F-gas inventory since the application was registered in 1998.

Optical fibre production
Both HFC and PFC are used for technical purposes in Danish optics fibre production.

HFC-23 is used as a protection and cleaning gas in the production process. The emission factor is therefore determined as 100 per cent release during production. The actual emission from HFC-23 is 4 200 tonnes CO_2 equivalents in 2010, a continuation of the increase seen from 2008 to 2009.

4.1.3 Emissions of sulphur hexafluoride

The total emission of SF_6 in 2010 has been calculated to 1.6 tonnes, equivalent to a GWP contribution of 38 400 tonnes CO_2 equivalents.

Emissions derive from three sources - power switches, double-glazed windows and laboratories.

Double-glazed windows
Use of SF_6 in double-glazed windows was phased out in 2002, however, there are still emissions from stock in existing double-glazed windows in Danish buildings. The stock is estimated from consumption data from Danish producers of double-glazed windows 1992-2002 and life time for double-glazed windows are determined to 20 years.

Emissions from double glazed windows are calculated on following factors:

- 15 per cent emission from production
- 1 per cent gradual emission from stock pr. year
- 65 per cent emission when disposal after 20 years

Table 4.8 Calculation parameters and emissions of SF_6 from double-glazed windows for 2010, 2015 and 2020, tonnes

	2010	2015	2020

Consumption	0,0	0,0	0,0
Emissions from production	0,0	0,0	0,0
Release from fitted douBMe-glazed windows	0,4	0,2	0,1
Exports	0,0	0,0	0,0
Disposal emissions	0,0	3,7	1,1
Stock	34,8	16,8	6,5
Actual emissions	0,4	3,9	1,2
GWP contribution, 1000 tonnes CO_2 equivalents	8,4	94,1	29,1

SF_6 emissions from existing double-glazed windows will increase in the coming years because of end of life and disposal of old windows containing SF_6. The future scenario for GWP contribution from double-glazed windows in 2015 shows an increase to 94 100 tonnes CO_2 equivalents to be compared with 8 400 tonnes CO_2 equivalents in 2010.

Power switches in high-voltage transmission stations

Power switches are filled or refilled with SF_6, either for new installation or during service and repair. Filling is usually carried out on new installations and a smaller proportion of the consumption of SF_6 is due to refilling /11/.

Emissions from power switches in high-voltage transmission systems are calculated due to the processes involved in the following way:

- release of 5 per cent on filling with new gas (average figure covering normal operation and failure/accidents)
- gradual release of 0.5 per cent from the stock (average figure covering normal operation and failure/accidents)
- release of 5 per cent from drawing off and recycling used gas (average figure covering normal operation and failure/accidents)

These figures are determined in a report of Danish SF_6 use in high-voltage power switches /11/.

No emissions are assumed to result from disposal since the used SF_6 is drawn off from the power switches and is either re-used internally by the concerned, or re-used externally through means of a collection scheme. Emissions resulting from external re-use are determined on the assumption that 0.5 per cent of the annual stock is sent for external re-use.

Table 4.9 shows the amounts involved in the processes leading to emissions and calculated actual emissions from SF_6 power switches.

Table 4.9 Calculation parameters and emissions of SF_6 from power switches in high-voltage plants 2010, 2015, and 2020, tonnes

	2010	2015	2020
Consumption	3,2	3,0	3,0
Service emissions	0,2	0,2	0,2
Recycling/recovery emissions	0,0	0,0	0,0
Emissions from stock	0,4	0,5	0,5
Stock	85,5	97,4	109,0

Actual emissions	0,6	0,6	0,7
GWP contribution, 1000 tonnes of CO_2 equivalents	14,2	15,4	16,8

Laboratory purposes

Consumption of SF_6 in laboratories covers two purposes:

- Plasma erosion in connection with the manufacture of microchips in clean-room laboratories
- Analysis purposes to a limited extend.

The emission is calculated to 0.6 tonnes SF_6 in 2010 and it was primary for plasma erosion purpose. The emission is 100 % release during consumption and estimated to 15 300 tonnes CO_2 equivalents.

4.1.4 Emissions of per fluorinated hydrocarbons

Commercial refrigerators

The PFC emissions from commercial refrigerators occur from stock and from a smaller use of PFC-14 (R413A which contain 9 % perfluorinated hydrocarbons). The actual GWP-weighted emission from this source is 7 tonnes CO_2 equivalents, which is a further reduction compared to the last eight years.

Stock in commercial refrigerators has been estimated at about 9 tonnes in 2010 and trend is going toward phasing out units using HFC blends with PFC refrigerants.

The emission calculations use the same parameters as described for HFC emissions from commercial refrigerators (see appendix 3). Refrigerants containing PFC are only used in stationary refrigerators. Therefore no estimates for imports and exports are relevant.

Table 4.10 Calculation parameters and emissions of PFCs from commercial refrigerators in 2010, 2015 and 2020, tonnes

	2010	2015	2020
Consumption	0,0	0,0	0,0
Emission ved påfyldning	0,0	0,0	0,0
Emission from stock	1,0	0,6	0,3
Stock	9,0	5,2	3,1
Actual emisison	1,0	0,6	0,3
GWP-contribution, 1000 tons CO2 equivalents	7,0	4,1	2,4

Optical fibre production

The PFC emission from optics fibre production is 2010. This sector use PFC-14 and PFC-318 for technical purpose in optics fibre production.

The PFCs are used as a protection and cleaning gas in the production process. The emission factor is therefore determined as 100 per cent release during production. The actual emission from PFC-14 and PFC-318 is estimated to 6.255 tonnes CO_2 equivalents in 2010.

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Appendix 1

GWP values for F-gases

Table 1.a
F-gases relevant for Denmark, their chemical formulas and Global Warming Potential (GWP) values used for reporting to the UN Climate Convention and the Kyoto Protocol

Substance	Chemical formula	GWP value
HFCs		
HFC-23		2 800
HFC-32	CH_2FH_2	650
HFC-125	C_2HF5	2 800
HFC-134a	CF_3CFH_2	1 300
HFC-152a	CF_2HCH_3	140
HFC-245		950
HFC-227	C_3HF_7	2 900
HFC-365		890
HFC-404A(1)	-	3 260
HFC-401A(2)	-	18
HFC-402A(3)		1 680
HFC-407c(4)		1 525
HFC-408A(5)		1 030
HFC-409A(6)		0
HFC-410A(7)		1 725
HFC-507A(8)		3 300
Sulphurhexafluoride	SF_6	23 900
PFCs		
PFC-14 (Isceon 49 contain 9%)	CF_4	6 500
PFC-318		10 300

(1) Mixture consisting of 52 % HFC-143a, 44 % HFC-125 and 4 % HFC-134a.
(2) Mixture consisting of 53 % HCFC-22, 13 % HFC-152a and 34 % HCFC-124.
(3) Mixture consisting of 38 % HCFC-22, 60 % HFC-125 and 2 % propane.
(4) Mixture consisting of 25 % HFC-125, 52 % HFC-134a, and 23 % HFC-32. (5) Mixture consisting of 46 % HFC-143a and 7 % HFC-125.
(6) A HCFC mixture consisting entirely of HCFCs, where the GWP - in accordance with the climate convention guidelines - is 0, since the mixture does not contain greenhouse gases. The real GWP value is 1,440.
(7) Mixture consisting of 50 % HFC-32 and 50 % HFC-125
(8) Mixture consisting of 50 % HFC-125, 50 % HFC-143a.

Assessment of Good Practice Guidance compliance in DK F-gas calculation

The Danish F-gas emissions are calculated for the historical years up to 2010. The time series of emissions are calculated using Good practice principles and the series goes back to 1993, but are to be considered complete from the year 1995.

Key Source Categories

F-gases are determined as a key source category. The contribution of F-gases to national greenhouse gas emission is approx. 1.3 % of total emission excl LULUCF in the most recent historical years of the inventories.

Future trend scenarios

A trend scenario is elaborated until 2020. The scenario is bases on a “steady state” trend but with an inclusion of dates for out phase of determined substances as stated in legal acts.

Methodology

In the following the relevant decision trees from the GPG (Good Practice Guidance) chapter 3 are investigated with respect to the Danish F-gas calculations compliance with GPG.

For the Danish calculation of F-gases it is basically a Tier 2 bottom up approach which is used, while data is reported from identified importers and users of F-gasses in DK. As for verification using import/export data a Tier 2 top down approach is applied. In an annex 4 to the F-gas emission report 2006 (Environmental Protection Agency), there is a specification of the applied approach for each sub source category.

Emission factors

Consumption data of F-gases are provided by suppliers and/or producers. Emission factors are primarily defaults from GPG which are assessed to be applicable in a national context.

In case of commercial refrigerants and Mobile Air Condition (MAC), national emission factors are defined and used. In case of PUR foam blowing of shoe and use of system foam EF are stated by the producer. Because of the relative low consumption from PUR foam blowing of shoes and system foam a certain uncertainty is assessed as acceptable.

Import/export data

Import/export data for sub category sources where import/export are relevant (MAC, fridge/freezers for household) are quantified on estimates from import/export statistic of products + default values of amount of gas in product. The estimates are transparent and described in the annex referred to above.

Import/export data for system foam and commercial refrigerators and stationary air condition are specified in the reporting from importers and users.

Consistency

The time series are consistent as regards methodology. No potential emission estimates are included as emissions in the time series and same emission factors are used for all years.

Reporting and documentation

The national inventories for F-gases are provided on a yearly basis and documented in a yearly report (Environmental Protection Agency, 2004 and 2005).

Detailed data from importers and users and calculations are available and archived in electronic version. The report contains summaries of EF used and information on sources, Further details on methodology and EF are included in annex to the report.

Activity data are described in a spread sheet for the current year. The spread sheet contains the current year as well as the years back. The current version is used with spreadsheet for data for the current year linking to the Danish inventory databases and for the CRF format. In case of changes to the previous reported data this is work out in spreadsheet versions accordingly and reported with explanations as required in the CRF format.

Source specific QA/QC and verification

Comparison of emissions estimates using different approaches

Inventory agencies should use the Tier 1 potential emissions method for a check on the Tier 2 actual emission estimates. Inventory agencies may consider developing accounting models that can reconcile potential and actual emissions estimates and may improve determination of emission factors over time.

This comparison has been carried out in 1995-1997 and for all three years it shows a difference of approx. factor 3 higher emissions by using potential emission estimates.

Inventory agencies should compare bottom-up estimates with the top-down Tier 2 approach, since bottom-up emission factors have the highest associated uncertainty. This technique will also minimise the possibility that certain end-uses are not accounted for in the bottom-up approach.

This exercise has been partly conducted since data from importers (top down) are assessed against data from users (bottom up) to ensure, that import and consumption are more or less equal. The consumption reported from users are always adjusted to the import of substances, which are the most exact data we have.

The uncertainty due to this is, if not all importers are identified because new imported are introduced to the DK market.

National activity data check

For the Tier 2a (bottom-up) method, inventory agencies should evaluate the QA/QC procedures associated with estimating equipment and product inventories to ensure that they meet the general procedures outlined in the QA/QC plan and that representative sampling procedures were used.

No QA/QC plan specifically for the F-gas calculation is developed. However, QC procedures were carried out as described below.

The spread sheets containing activity data has incorporated several data-control mechanisms, which ensure, that data estimates do not contain calculation failures. A very comprehensive QC procedure on the data in the model for the whole time-series has for this submission been carried out in connection to the process which provided (1) data for the CRF background Tables 2(II).F. for the years (1993)-2002 and (2) provided data for potential emissions in CRF Tables 2(I). This procedure consisted of a check of the input data for the model for each substance. As regards the HFCs this checking was done according to their trade names. Conversion was made to the HFCs substances used in the CRF tables etc. A QC was that emission of the substances could be calculated and checked comparing results from the substances as trade names and as the "no-mixture" substances used in the CRF.

Emission factors check

Emission factors used for the Tier 2a (bottom-up) method should be based on country-specific studies. Inventory agencies should compare these factors with the default values. They should determine if the country-specific values are reasonable, given similarities or differences between the national source category and the source represented by the defaults. Any differences between country specific factors and default factors should be explained and documented.

Country specific emission factors are explained and documented for MAC and commercial refrigerants and SF6 in electric equipment. Separate studies has been carried out and reported. For other sub source categories, the country specific emission factor is assessed to by the same as the IPCC default emission factors.

Emission check

Since the F-gas inventory is developed and made available in full in spread sheets, where HFCs data are for trade names, special procedures are performed to check the full possible correctness of the transformation to the CRF-format through Acces databases.

Uncertainties

In general uncertainty in inventories will arise through at least three different processes:

A. Uncertainties from definitions (e.g. meaning incomplete, unclear, or faulty definition of an emission or uptake);
B. Uncertainties from natural variability of the process that produces an emission or uptake;
C. Uncertainties resulting from the assessment of the process or quantity, including, depending on the method used,: (i) uncertainties from measuring; (ii) uncertainties from sampling; (iii) uncertainties from reference data that may be incompletely described; and (iv) uncertainties from expert judgement.

Uncertainties due to poor definitions are not expected as an issue in the F-gas inventory. The definitions of chemicals, the factors, sub source categories in industries etc. are well defined.

Uncertainties from natural variability are probably occurring in a short term time period, while estimating emissions in individual years. But in a long time period – 10-15 years, these variabilities levels out in the total emission , because input data (consumption of F-gases) are known and are valid data and has no natural variability due to the chemicals stabile nature.

Uncertainties that arise due to imperfect measurement and assessment are probably an issue for:

emission from MAC (HFC-134a)
emission from commercial refrigerants (HFC-134a)

lead to inexact values of the specific consumption of F-gases.

The uncertainty varies from substance to substance. Uncertainty is greatest for HFC-134a due to a widespread application in products that are imported and exported. The greatest uncertainty in the areas of application is expected to arise from consumption of HFC-404a and HFC-134a in commercial refrigerators and mobile refrigerators. The uncertainty on year to year data is influenced by the uncertainty on the rates at which the substances are released. This results in significant differences in the emission determinations in the short term (approx. five years), differences that balances in the long term.

I connection to the work on the Danish National Inventory report general uncertainty estimates for F-gases has been worked out to make the uncertainties for the Danish inventories complete. Refer this report given in the reference list in the main report

Further improvement of uncertainty analysis with respect to the calculation of F-gas emissions are to be considered in future calculations.

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Specification of methods and assumptions for determination of emissions for 1990-2010 as well as projections of GWP in accordance with *IPCC Good Practise Guidance and Uncertainty Management in National Greenhouse Gas Inventory*

ID	Source	Substance	Methods	Emission factor	Remarks	Projection assumptions
	OF SUBSTITUTES FOR OZONE-DEPLETING SUBSTANCES (ODS SUBSTITUTES)					
	Refrigerant					
K1	Household fridges and freezers	HFC-134a	Tier 2 top-down approach: - information on refrigerant consumption provided by reports from the main producers of household fridges and freezers in DK. information on refrigerant consumption provided by reports from the main producers of household fridges and freezers in DK, accounting for no less than an estimated 95% of the market. Tier 2 bottom-up approach: - information on imports and exports of refrigerants in products based on the average quantity contained per unit and Danish statistics.	- release on filling = 2% (IPCC default) 1 % release from stock per year (IPCC default) Lifetime = 15 years (IPCC default) 0% release upon disposal (DK default). Up to and including 2000, the quantity remaining upon disposal was included as emissions (IPCC default). Legislation in Denmark ensures drawing-off of refrigerant, and consequently, the IPCC default is misleading in the Danish context.	Stock determined in 1998 for the period 1990-1998 based on information on consumption from Danish producers and estimates based on import/export statistics and average quantity of HFC contained in refrigerant and foam per unit (source: /2/). For the updating of stock, import/export data from 1998 is used, as well as information on annual HFC consumption by Danish producers. 1998 import/export data is = net exports of 141 tonnes HFC-134a refrigerant + net exports of 1.6 tonnes HFC-134a in foam (note: DK's largest exporter does not use HFC for foam moulding, therefore the export of HFC in foam is less than the export of refrigerants).	From 2001, net exports of refrigerants in household fridges are assumed to account for 50 per cent of consumption. The consumption in the projection is not influenced by new phasing-out regulations. The effect of charges on HFCs is expected to give an annual reduction in consumption of 5 per cent in the period 2001-2005.

ID	Source	Substance	Methods	Emission factor	Remarks	Projection assumptions
K2	Commercial stationary refrigerators in retail stores, industry, etc., and stationary A/C systems in buildings etc.	HFC-134a, HFC-404a, HFC-401a, HFC-402a, HFC-407c, HFC-507a, other HFCs, PFCs (C_3F_8)	Tier 2 top-down approach: - information on refrigerant consumption was provided by importers/suppliers of refrigerants for commercial refrigerators in DK. - information on distribution of refrigerant consumption at different sites is estimated using information from user enterprises, the KMO and estimates from suppliers.	1.5% on refilling (DK default) 10% release from operation and accidents (DK default). 0% release from destruction (DK default) In the case of re-use it is assumed release occurs during the cleaning process equivalent to 2%. It is *good practice* not to account for any re-use since the original is accounted for in sales and imports.	In 2001/2002 an assessment was made of the national Danish leakage rate from commercial plants. This assessment was carried out by COWI for the Danish EPA. This result has led to a decrease in the leakage rates for filling, operation and disposal in compliance with IPCC guidelines /16/.	From 2007, the consumption of refrigerants merely represents the amount used for refilling existing systems (stock). It is assumed that the consumption of refrigerants for refilling stock will be reduced by 15 per cent in 2007 and will then diminish by 5 per cent per year until 2014. From 2015, it is assumed that consumption will only represent 10 per cent per year compared to current levels.
K3	Refrigerated vans and lorries	HFC-134a, HFC-404a	Tier 2 top-down approach - information on refrigerant consumption in refrigerated vans and lorries is based on consumption information from refrigerated transport companies as well as data from the KMO.	0.5% on refilling (DK default) 17% from operation annually (DK default, same as IPCC) 2% in reuse (DK default) Lifetime = 6-8 years 0% upon destruction; all refrigerants are drawn off and are either recycled or destroyed at the Kommune Kemi plant	In 2001/2002 an assessment was made of the national Danish leakage rate from refrigerated vans and lorries. This assessment was carried out by COWI for the Danish EPA. This result has led to a decrease in the leakage rates for filling and disposal in compliance with IPCC guidelines. The leakage rate for operation is still 17% in compliance with IPCC guidelines /16/.	The tax effect has not been included, since refrigerated vans and lorries are exempt from taxes. Stock is defined as 7.7 tonnes (HFC-134a) and 23.2 tonnes HFC-404a in 2000 /16/. Consumption has been projected as steady state compared to 2001.
K4	Mobile A/C systems	HFC-134a	Tier 2 bottom-up and top-down approach. Bottom-up approach for definition of Danish emission factor and estimate for stock and imports. Top-down approach used for gathering of consumption data from importers for refilling of mobile A/C systems.	0.5% on refilling (DK default) 33% annual release during operation (complete refilling every 3 years - DK default). Lifetime for mobile A/C systems that are serviced is 6 years, equivalent to two refillings. Systems do not undergo maintenance after 6 years (DK default). 0% loss at destruction. Gas is collected and re-used/cleaned, or treated at Kommune Kemi (DK default). Emissions are calculated as 1/3 of stock from the previous year (n-1).	In 2001/2002 an assessment was made of the national Danish leakage rate from mobile A/C systems. This assessment was carried out by COWI for the Danish EPA. This result has led to a small increase in the leakage rate for operation and a decrease for filling and disposal in relation to IPCC guidelines /16/. The stock figures are updated using statistics on vehicles in Denmark from DAF. The average expected filling for cars and vans is 750 g, 1.2 kg for lorries under 6	The projection is based on a steady state stock (203 tons).

ID	Source	Substance	Methods	Emission factor	Remarks	Projection assumptions
				This means the stock is the central calculation parameter. The stock is calculated using DAF annual statistics in relation to a number of conditions defined in /16/. Consumption per annum gives the quantity used in refilling systems which undergo servicing (max. 50% of existing systems).	tonnes, 1.5 kg for lorries over 6 tonnes, and 9 kg for buses. Further calculation assumptions appear from /16/.	
	Foam production					
S1	Foam in household fridges and freezers (closed cell)	HFC-134a	Tier 2 top-down + bottom-up approach: - information on refrigerant consumption provided by reports from the main producers of household fridges and freezers in DK. information on refrigerant consumption provided by reports from the main producers of household fridges and freezers in DK, accounting for no less than an estimated 95% of the market.	10% release in foam production (IPCC default) 4.5% release from stock per year (IPCC default) Lifetime = 15 years (DK default) 22.5% remaining upon disposal which is destroyed in incineration and thereby is not released as emissions (DK default).	Stock of HFC in foam determined in 1998 for the period 1990-1998 based on information from Danish producers and estimates based on import/export statistics and average quantity of HFC contained in refrigerant and foam per unit /2/. For the updating of stock, import/export data from 1998 is used, as well as information on annual HFC consumption by Danish producers. 1998 import/export data is = net exports of 141 tonnes HFC-134a refrigerant + net exports of 1.6 tonnes HFC-134a in foam (note: DK's largest exporter does not use HFC for foam moulding, therefore the export of HFC in foam is less than the export of refrigerants).	
S2	Soft foam (open cell)	HFC-134a HFC-152a Other HFCs (HFC-365)	Tier 2 - information on foam blowing agents for soft foam is derived from reports provided by the main producer in Denmark, which still employs HFC in foaming processes. This producer is thought to represent approx. 80% of the Danish soft foam consumption.	Emissions = 100% of the HFCs sold in the current year (IPCC default)		
S3	Joint filler (open cell)	HFC-134a HFC-152a	Tier 2 top-down approach. - There are no longer any Danish producers of joint filler employing HFC as a foaming agent. Emissions are due to previous estimates by producers of imported joint filler products.	Emissions = 100% of imported quantity contained in joint filler in the current year (IPCC default).	The estimated imports in 1998 by a joint filler producer were 10 tonnes HFC-134a and 1 tonne HFC-152a. This estimate was based on the assumption that there is an average of 100 g HFC-134a and 25 g HFC-152a per tin of joint filler imported.	

ID	Source	Substance	Methods	Emission factor	Remarks	Projection assumptions
S4	Foaming of polyether (for shoe soles)	HFC-134a HFC-152a	Tier 2 top-down approach Information regarding consumption is identical to the consumption reported by producer in 1999 + an estimate of imports/exports of HFC in shoe soles, 1998. Tier 2 bottom-up approach: Imports of HFCs contained in shoes are based on the average amount per shoe and on Danish statistics.	Emission (Danish default): - Production = 15 % - Use = 4.5 % - Lifetime = 3 years - Disposal = 71.5%, destroyed in incineration and thereby not released as emissions.	The calculation of the HFC stock in shoe soles is based on the following assumptions: it is assumed that 5% of all shoes with plastic, rubber and leather soles contain polyether containing 8 g of HFC-134a per shoe. Net export with the same consumption in Danish production is 0.3 tonnes HFC-134a.	
S5	System foam (for panels, insulation, etc.)	HFC-134a HFC-152a Other HFCs (HFC-365)	Bottom-up Tier 2 approach on the basis of information from enterprises	Emissions = 0. HFC is used as a component in semi-manufactured goods and emissions first occur when the goods are put into use.	All system foam produced in Denmark is exported, therefore emissions can only occur in the country where the goods are put into use.	
	Aerosols					
D1	Aerosol sprays (industrial products)	HFC-134a	Tier 2. - information on propellant consumption is derived from reports on consumption from the only major producers of HFC-containing aerosol sprays in Denmark. The importers are estimated to account for 100% of Danish consumption.	Emissions = 50% of the HFC sold to this area of application in the current year and 50% of the consumption in the second year (IPCC default for top-down data)	Top-down data. Estimates of imports/exports are based on the producer's assessment of imports equivalent to 20% of Danish production in the current year. Exports are quantified by the producer.	
D2	MDI (metered dose inhalers)	HFC-134a	Tier 2 bottom-up approach - information on consumption is based on data from the national medical trade statistic concerning total sale of MDI in Denmark. Data from producers concerning product content of HFC-134a is used to calculate amount used pr. year. A unit factor of 72 mg HFC-134a/pr. dose are used for the calculation.	Emissions = 100 % HFC used in these products are assumed to be consumed the same year.	HFC is used in MDI as a subsidiary for effective inhale of the medicine. It is assumed that 100 % of the subsidiary emits.	
	Solvents					
R1	Liquid cleaners	PFC (C_3F_8 Perfluorpropan e)	Tier 2. - information on consumption of PFC in liquid cleaners is derived from two importers' sales reports. This is thought to represent 100% of the Danish consumption of PFCs in liquid cleaners.	Emissions = 50% of the HFC sold to this area of application in the current year and 50% of the consumption in the second year (IPCC good practice for top-down data)		Top-down data Phasing-out cf. Statutory Order 1/9 2002. It is assumed that the consumption is equally distributed over all months.
	Others					
O1	Fibre Optics production	PFC-14 PFC-318 HFC-227	Tier 2. - information on consumption of PFC in production of fibre optics is derived from importers' sales report with specific information on the amount used for production of fibre optics.. This is thought to	Emission = 100% in the production year = year for consumption	This is a new consumption area which are added for first time in 2006 emission calculation.	It is considered that consumption will be steady state in projection estimated.

ID	Source	Substance	Methods	Emission factor	Remarks	Projection assumptions
			represent 100% of the Danish consumption of PFC-14 and PFC-318 for that purpose			
	EMISSIONS OF SF_6 FROM ELECTRICAL EQUIPMENT AND OTHER SOURCES					
	Insulation gas in double glazing	SF_6	Tier 2 - information on consumption of SF6 in double glazing is derived from importers' sales reports to the application area. The importers account for 100% of the Danish sales of SF_6 for double glazing. In addition, the largest producer of windows in Denmark has provided consumption data, with which import information is compared.	Emission (DK-default): - 15% during production of double glazing. - 1 % per year during the lifetime of the window - Lifetime = 20 years - Disposal - 66% of the filled content of double glazing in the production year. - Net exports = 50% of the consumption in the current year		Emissions data and lifetimes are based on information from the window producers and industry experts in Denmark /2/. The stock is determined on the basis of consumption information provided by importers back to 1990. The first Danish consumption was registered in 1991. In the projection of emissions, it is assumed that the consumption of SF_6 in Danish window production was phased out in 2003, after which emissions only arise from stock.
	Insulation gas in high-voltage power switches	SF_6	Tier 3c country-level mass-balance approach - information on consumption of SF_6 in high-voltage power switches is derived from importers' sales reports (gas or gas-containing products). The importers account for 100% of the Danish sales of SF_6. The electricity sector also provides information on the installation of new plant and thus whether the stock is increasing.	Emission (Danish default): - release on filling = 5% - loss / release in operation = 0.5 % per year - release in reuse/drawing off = 5%. - release upon disposal = 0%		There is one supplier (Siemens) that imports its own gas for filling in Denmark. Suppliers (AAB, Siemens, Alstom) report on new installations. The stock in 2000 was 57.6 tonnes of SF_6, which covers power switches of all sizes in production and transmission plants. The stock has been evaluated on the basis of a questionnaire survey in 1999 which encompassed the entire Danish electricity sector /11/.
	Shock-absorbing gas in Nike Air training footwear	SF_6	Tier 2 - top-down approach Importer has estimated imports to Denmark of SF_6 in training footwear.	Lifetime training footwear = 5 years		Importer/wholesaler reports that imports for the period 1990-1998 amounted to approx. 1 tonne, equivalent to emissions of 0.11 tonnes per year in the period 1995-2003. For the period 1999-2005, the importer estimated imports to represent approx. 1/3, corresponding to 0.037 tonnes per year in the period 2004-2010.

Summary
The consumption of the industrial fluorinated greenhouse gases totalled app. 4358 tonnes in 2010. This is a decrease of app. 10 tonnes compared to 2009. The GWP-weighted actual emission was 854.000 tonnes, in 2010. This is a small and most probably random increase compared to 2009. The increase can be assigned to HFC 134A.

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