DANISH MINISTRY OF THE ENVIRONMENT

Environmental Protection Agency

Ozone-depleting substances and the greenhouse gases HFCs, PFCs and SF_6

Danish consumption and emissions, 2005

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Contents

APPENDICES

1 Summary

1.1 Ozone-depleting substances

ODP-weighted consumption for 2005 based on reporting from importers has been calculated at 1.76 ODP tonnes, a further reduction of 1.07 ODP tonnes compared to 2004, when consumption was 2.83 ODP tonnes.

Due to this, Statistics Denmark registered imports of 14.2 tonnes of CFC-12 in 2005. Import of CFC-12 is banned and therefore this registration is undergoing an investigation to clarify whether the import is actual or it is coursed data failure.

The table below shows ODP-weighted consumption calculated on the basis of information on imports from importers and producers. The ODP values are listed in Appendix 1, Table 1.a.

Table 1.1 Overview of consumption and ODP-weighted consumption in 2002-2005, Tonnes

Substance	Net consumption, 2002	ODP-weighted consumption, 2002	Net consumption, 2003	ODP-weighted consumption, 2003	Net consumption, 2004	ODP-weighted consumption, 2004	Net consumption, 2005	ODP-weighted consumption, 2005
CFCs (1)	0.95	0.76	0.1	0.08	0.001	0	0.001	0
Tetrachloro-methane	0.87	0.96	0.36	0.39	0.033	0.036	0	0
1,1,1-Trichloroethane	0.02	-	0.02	-	0.009	-	0.01	-
Halons	0	0	0	0	0	0	0	0
Methyl bromide	(only feedstock)	-	(only feedstock)	-	-	-	-	-
HCFCs	390	41.25	204.65	16.88	142.68	2.79	114.3	1.76
HCFC-22 (new)	24.5	1.35	96,7	5.3	0	0	0	0
HCFC-22 (regenerated)	-	-	-	-	112.1	0	95.6	0
HCFC-22 (HFC mix)	-	-	-	-	10.3	0.56	5.3	0.29
HCFC-123	-	-	-	-	-	-	-	-
HCFC-141b	360	39.6	102.35	11.26	20.28	2.23	13.4	1.47
HCFC-142b	0	0	0	0	0	0	0	0
Total		42.97		17.36		2.83		1.76

(1) In the calculation of the ODP-weighted consumption of CFCs, CFC-113 is the only substance which has been reported and which is included in the calculation basis.

Danish consumption of methyl bromide has only been used as feedstock for other chemical production. Therefore it is not included as an emission.

CFCs, tetrachloromethane, and trichloroethane are used exclusively for laboratory purposes.

HCFCs are used as refrigerants or for foam production (system foam). The areas of application of HCFCs in 2005 are shown in Table 1.2.

Table 1.2 Consumption of HCFCs by application area in 2005, tonnes.

Application area	HCFC-22	HCFC-123	HCFC-141b	HCFC-142b
System foam (for panels, insulation, etc.)	0	0	13.4	0
Refrigerants, New	0	0	0	0
Refrigerants, regenerated	95.6	0	0	0
Refrigerants, HFC mixtures	5.3	0	0	0
Total	100.9	0	13.4	0

Only regenerated HCFC-22 is used as a refrigerant in Denmark and import of new HCFC-22 is exported to other countries for use as refrigerant. Regenerated HCFC-22 is not included in calculation of the ODP weighted consumption.

HCFC-141b is used in foam production

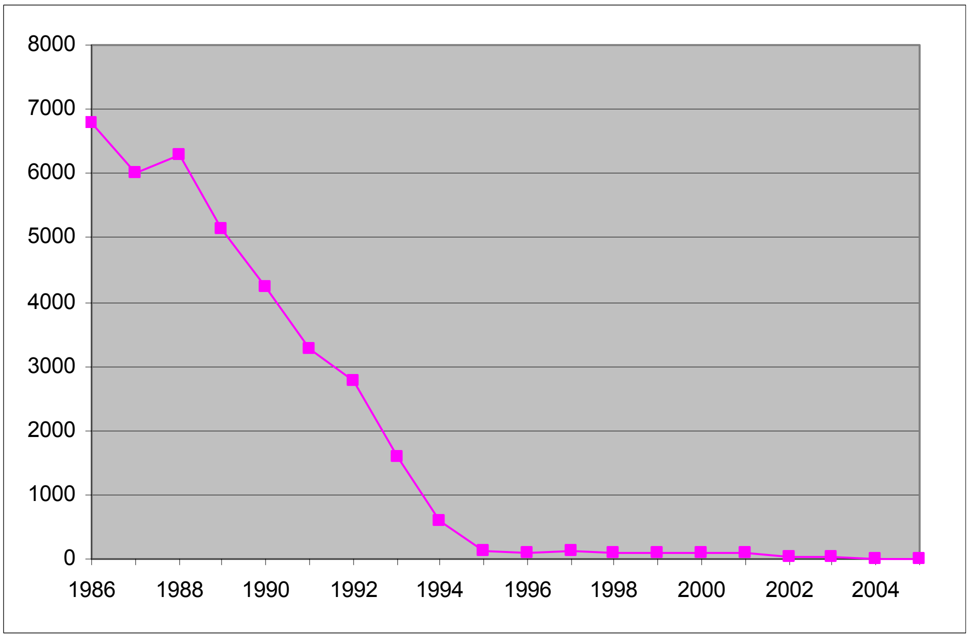

Figure 1.1 The development of ODP-weighted consumption 1986-2005, tonnes.

The specific consumption figures for individual substances and groups of substances and the ODP contribution calculated for the period 1992-2005 appear in Table 3.1 in Chapter 3.

1.2 F-gases

The GWP-weighted actual emissions of HFCs, PFCs, and SF_6 in 2005 were 839,5 thousand tonnes CO_2 equivalents. The corresponding emissions were 796,8 thousand tonnes CO_2 equivalents in 2004, as reported in /13/. Thus, the consumption of HFC has decreased with approx. 150 tonnes in 2005 compared to 2004. The increase in the GWP-weighted actual emission is first of all an effect of historical consumption in refrigeration systems which have a large amount of refrigerants in stock.

In Table 1.3 below, consumption, actual emissions and stock in products are summarised after making adjustments for any imports and exports of stock in products.

Table 1.3 Consumption, actual emissions, stock, adjusted for imports/exports as well as GWP contribution from greenhouse gases 2005, tonnes.

Source	Substance	Consump-tion 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	112.8	836.6	82.3	106990	
	HFC-404a	151.3	1057.0	103.2	336285	
	HFC-401a	0.0	16.3	2.0	37	
	HFC-402a	0.0	24.3	2.8	4697	
	HFC-407c	61.6	378.6	36.2	55280	
	HFC-507a	5.4	60.9	6.3	19410	
	Other HFC-er	14.5	108.6	10.7	18446	
	PFC	0.5	17.6	2.0	13904	
	Sum					555048
Household fridges/freezers						
Refrigerants	HFC-134a	65.5	820.7	9.3	12068	
	HFC-404a	3.7	79.8	0.9	2871	
Insulation foam	HFC-134	0.8	1225.9	78.2	101659	
	HFC-152	0.0	2.3	0.1	15	
	Sum					116613
Refrigerants for mobile A/C systems	HFC-134a	33.3	213.0	64.9	84317	84317
Refrigerated vans and lorries	HFC-134a	0.5	5.7	1.1	1428	
	HFC-404a	7.4	33.6	5.8	18954	
	HFC-402a	0.0	1.5	0.3	508	
	Sum					20890
Other PUR foam and system foam	HFC-134a/245	52.0	49.3	8.9	11593	11593
Soft foam and aerosol sprays etc.	HFC-134a	26.9		22.4	29120	
	HFC-152a	5.5		5.5	193	
	Sum					29313
System foam	HFC-134a	0.0		0.0	0	
	HFC-152a	0.0		0.0	0	
	HFC-365	12.0		0.0	0	
	Sum					0
Liquid cleaners	PFC	0.0		0.0	0	0
Double glazing	SF6	0.0	38.3	0.4	9252	9252
High-voltage power switches	SF6	3.6	67.9	0.5	12501	12501
Laboratories	SF6	0.0		0.0	0	0
Total	HFC-er	559.4	4914.1	440.9	803871	
	PFC-er	0.5	17.6	2.0	13904	
	SF6	3.6	106.2	0.9	21753	
GWP contribution	Total				839527	

In Figure 1.2 below, total GWP contributions from HFCs, PFCs, and SF_6 are shown in relation to individual sources. The figure shows the sources responsible for individual contributions in 2005.

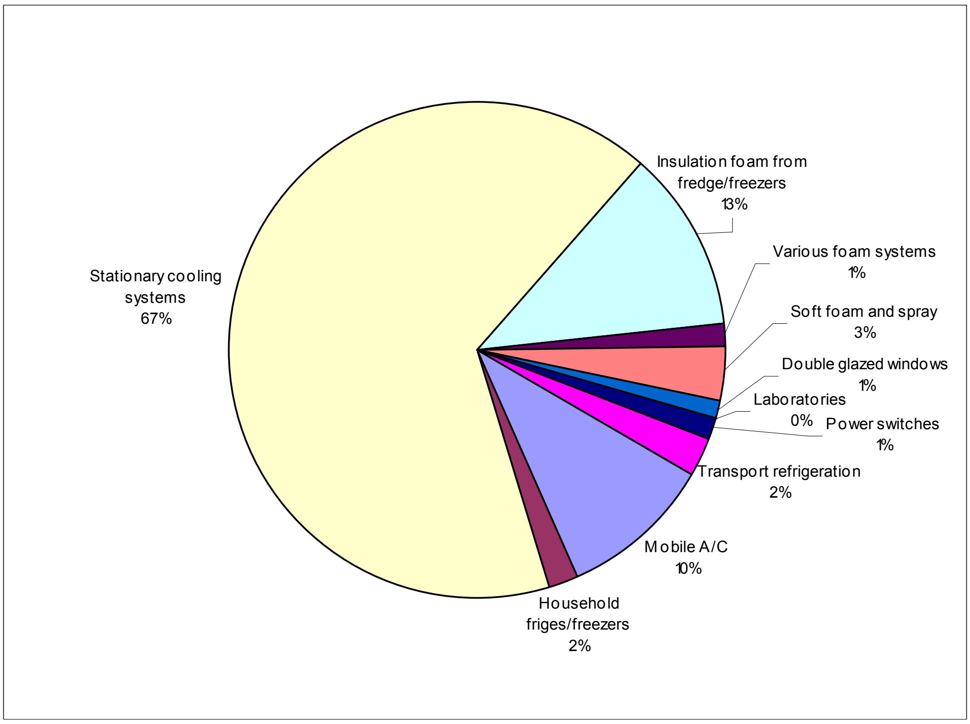

Figure 1.2 The relative distribution in 2005 of GWP contribution, analysed by source

The figure shows that emissions from refrigerants used in commercial stationary refrigerators account for the largest GWP contribution. These refrigerators cover 66,1 per cent of the total actual contribution in 2005. The contribution is primarily from HFCs, and a small part is from PFCs.

The second-largest GWP contribution, accounting for 12.1 per cent, comes from ongoing releases of HFCs from insulating foam and insulation foam in fridges and freezers.

Mobile A/C contribute with 10 per cent and 3.5 per cent of the GWP contribution stems from HFC emissions released during the production of soft foam and from the use of HFC-based aerosol sprays.

The two sources of SF_6 emissions in 2005 were power switches and double glazing windows. These account for 2.6 per cent of the total GWP contribution.

HFCs comprise around 95.8 per cent of the overall GWP contribution in 2005. Emissions of SF_6 comprise 2.6 per cent and emissions of PFC contribute with 1.7 per cent to the total contribution.

The relative distribution is shown in Figure 1.3 below.

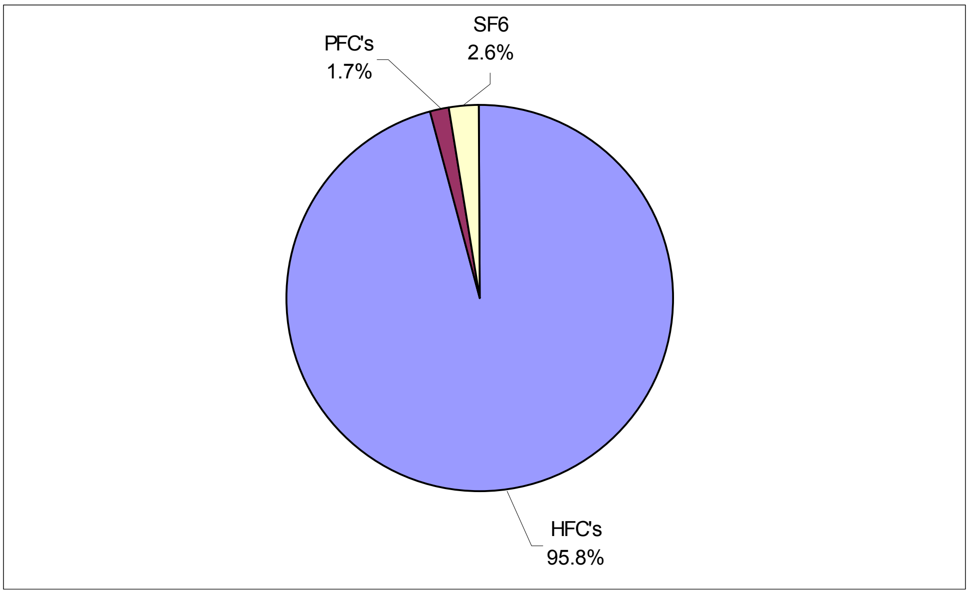

Figure 1.3 The relative distribution of the GWP contribution from HFCs, PFCs, and SF_6, 2005.

1.2.1 HFCs

In 2005, the total import (minus re-export) of pure HFCs was approx. 553.7 tonnes. When including import of R 413 and R 417 HFC blends, the total netto import of pure HFC's are 559.4 tonnes. Compared to 2004, when total consumption was approx. 711.5 tonnes, the import is decreased.. There are reductions for almost all HFCs. Only import of HFC-245 has increased.

Actual emissions from HFC's have been calculated to approx. 803,9 thousand tonnes CO_2 equivalents. In 2004, emissions were 747,7 thousand tonnes CO_2 equivalents. It is an increase of approx. 55,000 tonnes CO_2 equivalents

The actual emission from HFC's has exceeded to highest level since HFC's has been introduced.

1.2.2 Sulphur hexafluoride (SF_6)

The consumption of sulphur hexafluoride was 3.58 tonnes in 2005, which is an increase of approx. one tonnes compared to 2004.

Actual emissions have been calculated at 0.9 tonnes, equivalent to a GWP contribution of 21.7 thousand tonnes CO_2 equivalents. In 2004, emissions were 33.1 thousand tonnes CO_2 equivalents.

1.2.3 Per fluorinated hydrocarbons (PFCs)

In 2005, the consumption of per fluorinated hydrocarbons (per fluoropropane), which are used exclusively in the refrigerant R413a, was 0.5 tonnes. The actual GWP-weighted emission from stock containing R413a and consumption is 13.9 thousand tonnes CO_2 equivalents, which is a continuation of the reduction since 2002.

1.2.4 Trends in total GWP contribution from F-gases

Figure 1.4 shows the trend in Danish GWP contributions 1992-2004 from HFCs, PFCs, and SF_6. The differences from the present calculations of the total GWP value compared with earlier calculation methods are illustrated in the figure.

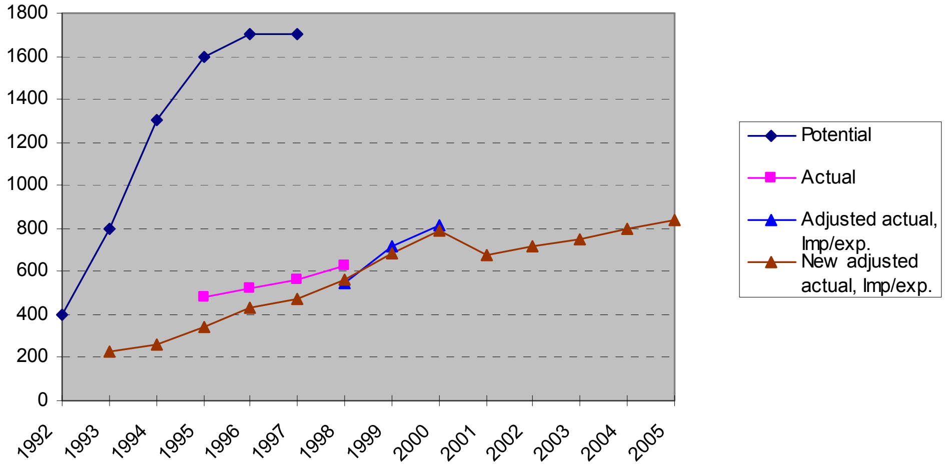

Figure 1.4 Trends in GWP-weighted potential, actual and adjusted actual emissions 1992-2005, 1000 tonnes CO_2 equivalents.

The figure shows that the GWP emission also in 2005, has increased and now the emission from F-gases has exceeded the highest level ever.

The development in the GWP contribution 1992-2005 can also be seen in Table 1.4 below.

Table 1.4 Total GWP-contribution from HFCs, PFCs, SF_6, 1000 tonnes CO_2 equivalents, determined according to the four different methods of calculation applied during this period

	Potential	Actual	Actual, adjusted imp/exp.	New actual, adjusted imp/exp.
1992	400			
1993	800			230
1994	1300			263
1995	1600	480		344
1996	1700	520		435
1997	1700	560		472
1998		625	577	564
1999			700	683
2000			818	793
2001				699
2002				719
2003				745
2004				797
2005				839

2 Introduction

On behalf of the Danish Environmental Protection Agency (Danish EPA), the consulting firm PlanMiljø carried out an evaluation of Danish consumption and emissions of ozone-depleting substances and the industrial greenhouse gases, or so-called F-gases, HFCs, PFCs, and SF_6 for 2005. The evaluation was carried out in continuation of previous evaluations /13/ and references in these.

The evaluation includes a calculation of actual emissions of HFCs, PFCs, and SF_6. In this calculation of actual emissions, the release from stock of greenhouse gases in products has been taken into account, and adjustments have been made for imports and exports of the greenhouse gases in products. Appendix 5 describes the specific emission factors, etc.

The evaluation was partly prepared to enable Denmark to fulfil its international obligations to provide information within this area, and partly to follow the trend in consumption of ozone-depleting substances as well as the consumption and emissions of HFCs, PFCs, and SF_6. An example of reporting of Danish emissions is given in reference /18, 19, 21/, and most recently, in reference /23/.

The ozone-depleting substances regulated by the Montreal Protocol are depleting the earth’s protective ozone layer at a much greater rate than natural processes reproduce ozone. This is disturbing the natural balance and leading to an increase in dangerous ultraviolet radiation. The depletion is dependent on the different ozone-depleting potentials of the specific substances: their ODP values (Ozone-Depleting Potential).

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 is rising and this leads to climate changes. There are several ozone-depleting substances that also have a strong greenhouse effect.

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 that do not have an ozone-depleting effect, but which have high GWP values (HFCs, PFCs and SF_6) are regulated by the Kyoto Protocol under the Climate Change Convention.

The Danish EPA has published a booklet on the ozone layer and the greenhouse effect /5/, and in cooperation with the other Nordic countries, the Danish EPA has published a booklet on the protection of the ozone layer - Nordic Perspective /6/. The Danish EPA has also published a report on substituting the greenhouse gases HFCs, PFCs and SF_6 /10/.

2.1 Monitoring Group

The project was overseen by a monitoring group. The monitoring group reviewed the evaluation results. The monitoring group consisted of:

- Frank Jensen, Danish EPA
- Mikkel Aamand Sørensen, Danish EPA
- Erik Lyck, National Environmental Research Institute, Denmark (NERI)
- Lau Vørs, AKB Denmark (Authorized Refrigeration Installers Association)
- Torkil Høft, KMO
- Sven-Erik Jepsen, Confederation of Danish Industries (DI)
- Tomas Sander Poulsen, PlanMiljø

2.2 Objective

The objective of this project was to map the 2005 consumption of newly produced industrial ozone-depleting substances and the consumption and actual emissions of HFCs, PFCs, and SF_6. The evaluation was made in accordance with the IPCC guidelines (Intergovernmental Panel on Climate Change) /4/, and following the method employed in previous evaluations.

In Appendix 1, Tables 1.a and 1.b show the ozone-depleting substances regulated by the Montreal Protocol, their chemical formulas and ODP values (Ozone-Depleting Potential), and the potent industrial greenhouse gases covered by the Kyoto Protocol under the Climate Change Convention, including their chemical formulas and GWP values (Global Warming Potential).

2.3 Scope and definition

Ozone-depleting substances

This evaluation covers the net consumption of ozone-depleting substances. The term "net consumption" is understood as the amount of imported goods in bulk or drums, less any re-export of substances as raw materials.

Ozone-depleting substances contained in finished products that are imported and exported are not included in the evaluation. This delimitation is in full compliance with international guidelines.

The evaluation does not account for the consumption of ozone-depleting substances used as raw material in the production of other substances, such as tetra chloromethane, and which are not subsequently emitted to the atmosphere.

The information on consumption has been gathered from importers, suppliers and enterprise end-users (usually purchasing departments), and Statistics Denmark. This method of data gathering means that the information gathered is about the quantities of substances traded. Purchase and sales figures are used as an expression of consumption. This approach is considered to be suitable and adequate for the present purpose, since experience from previous projects shows that a levelling out occurs with time and that the substances sold/purchased are consumed within a relatively small time horizon.

None of the substances covered here are produced in Denmark. Furthermore, ozone-depleting substances are treated at chemical waste processing plants in Denmark. Treatment and destruction data was gathered for the evaluation, but in line with all previous evaluations it has not been accounted for in the consumption figures.

F-gases

The evaluation of the actual emissions of HFCs, PFCs and SF_6 was carried out in continuation of previous evaluations, which have become increasingly more comprehensive and accurate in step with the development of internationally approved guidelines (IPCC Guidelines) and guidance (IPCC Good Practice Guidelines) 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/.

2.4 Methods

Consumption and emissions

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

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

Information for the present evaluation was first gathered by means of a questionnaire survey. The responses to the questionnaires were supplemented where necessary with information gathered by telephone.

The results of the project are primarily based on the information received from enterprise and importer respondents etc., as well as reports and statistics from KMO, etc.

The information gathered from importers and suppliers was compared with information from consumer enterprises in order to monitor any discrepancies between purchase and sales information and application of the 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 due in part 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 evaluation was conducted using two different methods /4/:

- Potential emissions (ozone-depleting substances)
- Actual emissions (HFCs, PFCs, and SF_6)

The ozone-depleting substances are not included in the calculations of emissions of greenhouse gases, since ozone-depleting substances are regulated by the Montreal Protocol. When evaluating emissions of ozone-depleting substances, net consumption is considered equivalent to *potential emissions*. Thus:

Potential emissions = imports + production - exports - destruction/treatment.

The evaluation of greenhouse gas emissions 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 the grounds of the following analyses:

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 analyses were carried out within selected areas over a number of years. The analyses quantified the stock and, in some cases, Danish emission factors. Detailed analyses were carried out for commercial refrigerators, mobile A/C systems, fridges, freezers, and SF_6 power switches. Analyses 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 greatest for HFC-134a due to its widespread application in products that are imported and exported. The greatest 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 out in the long term. This is because the breakdown is only significant for the rate at which emissions are released.

Appendix 5 shows an overview of all application areas included with descriptions of the bases of calculation.

2.5 Explanation of terminology

The following terms and abbreviations are used throughout this report:

- *Enterprise end-user:* A producer that uses ozone-depleting substances or 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 products in use in Denmark.

3 Ozone-depleting substances

All known importers of ODSs responded to the questionnaire survey. The responses provide information on imports/exports, sales/purchases, and areas of application for relevant substances (including both mixed and pure substances). All ODSs reported by the importers are newly produced ODSs.

The information from importers was supplemented with statistical information from Statistics Denmark for 2005. Statistical data was used to cross-check imports/exports information from importers. The statistics do not distinguish between new and re-used substances, and thus imports could, in principle, consist of both new and re-used substances.

The foreign trade statistics for 2005 assign the following ozone-depleting substances to the following separate positions:

- CFC-11 (position no. 2903.41.00)
- CFC-12 (position no. 2903.42.00)
- CFC-113 (position no. 2903.43.00)
- CFC-115 (position no. 2903.44.90)
- Tetrachloromethane (carbon tetrachloride) (position no. 2903.14.00)
- 1,1,1-trichloroethane (methyl chloroform) (position no. 2903.19.00)

The foreign trade statistics also include some substance group positions that can indicate trends in imports and exports of HCFCs (and HFCs and PFCs), but due to the broad definitions of the substance groups, it is not possible to utilise the position numbers in the evaluation since this relates to individual substances.

3.1 Imports and exports

The following sections describe imports and sales of individual ozone-depleting substances.

3.1.1 CFCs

On the basis of information from importers, sales of new CFCs in 2005 were 0.01 tonnes. In 2004, sales were similar.

One importer reports having sold 0.01 tonnes of CFC-113 for laboratory purposes.

Statistics Denmark registered imports of 0 tonnes of CFC-113, 0 tonnes CFC-11, and 14.2 tonnes of CFC-12 in 2005. Import of CFC-12 is banned and therefore enterprises' calculations are being re-examined for correctness.

3.1.2 Tetrachloromethane

In 2005, information from companies on imports and sales of tetrachloromethane were 0 tonnes. In 2004, imports and sales were 0.033 tonnes.

Statistics Denmark registered imports of 0.059 tonnes in 2005. Because of the small amount, no re-examination for correctness, has been investigated.

3.1.3 1,1,1-Trichloroethane

In 2005 the information from companies on import of 1,1,1-Trichlorethane were 0.01 tonnes. In 2004 the import of 1,1,1-Trichlorethane were 0.009 tonnes. There were no reports of 1,1,1-trichloroethane in 2003.

Statistics Denmark registered imports of 0.002 tonnes in 2005. Because of the small amount, no re-examination for correctness, has been investigated.

3.1.4 Halons

There were no imports of halons in 2005. Halons have been phased out for several years.

3.1.5 Methyl bromide

Methyl bromide was only imported for feedstock in 2005.

3.1.6 HCFCs

Six enterprises imported HCFCs in 2005.

Consumption of HCFC-22 and HCFC-141b has gone down. There has been no consumption of HCFC-142b.

In 2005, imports of HCFC-22 (regenerated) were about 95.6 tonnes and import through HFC mixtures were 5.3 tonnes..

Imports of HCFC-141b were 13.4 tonnes in 2005. In 2004, imports totalled 20.3 tonnes.

There were no imports of HCFC-142b in 2005, and Danish consumption of this substance has been phased out.

Table 3.1 Developments in consumption and potential emissions, tonnes (ODP-weighted tonnes are shown in italics).

Substance	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
CFC-11	1,307	593	54	0	0	0	0	0	0	0	0	0	0	0
	1,307	*593*	*54*								-	-	-	-
CFC-12	612	495	243	0	0	0	0	0	0	0	0	0	0	0
	612	*495*	*243*								-	-	-	-
CFC-113	253	162	70	3	5	2	1.4	3.3	4.8	2.6	0.95	0.1	0.001	0.001
	202.4	*129.6*	*56*	*2.4*	*4*	*1.6*	*1.12*	*2.64*	*3.84*	2.08	*0.76*	*0.08*	-	-
CFC-115	56	50	26	0	0	0	0	0	0					
	33.6	*30*	*15.6*											
All CFCs	2.228	1.300	393	3	5	2	1.4	3.3	4.8	2.6	0.95	0.1	0	0
ODP-weighted consumption	*2,155*	*1247.6*	*368.6*	*2.4*	*4*	*1.6*	*1.12*	*2.64*	*3.84*	*2.08*	*0.76*	*0.08*	*0*	*0*
Tetrachloro-methane	3	<1	0.7	1.7	1.5	2.0	0.7	1.3	0.6	1.25	0.87	0.36	0.033	0
ODP-weighted consumption	*3.3*	*1*	*0.77*	*1.87*	*1.65*	*2.2*	*0.77*	*1.43*	*0.66*	*1.26*	*0.96*	*0.4*	*0.036*	*0*
1,1,1-Trichloro-ethane	1,015	940	569	104	0	0.9	0.2	0.03	0	0.05	0.002	0.025	0.009	0.01
ODP-weighted consumption	*101.5*	*94*	*56.9*	*10.4*	*0*	*0.09*	*0.02*	*0.003*	*0*	*0.005*	-	*0.0025*	-	-
Halon 1302	45	14	5	0	0	0	0	0	0	0	0	0	0	0
	450	*140*	*50*											
Halon 1211	4	1	0	0	0	0	0	0	0	0	0	0	0	0
	12	*3*												
Halon 2402	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0
			4.2											
All halons	44	15	6	0	0	0	0	0	0	0	0	0	0	0
ODP-weighted consumption	*462*	*143*	*54.2*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Methyl bromide[1)]	31	17	12	9	8	5	0	0	0	Only feed-stock	Only feed-stock	Only feed-stock	Only feed-stock	Only feed stock
ODP-weighted consumption	*18.6*	*10.2*	*7.2*	*5.4*	*4.8*	*3*	*0*	*0*	*0*	-	-	-	-	.
HCFC-22 (new + reg)	1,005	813	750	748	610	600	534	566	347	249.1	24.5	96.7	112.1	95.6
	55.3	*44.7*	*41.2*	*41.1*	*33.5*	*33*	*29.4*	*31.1*	*19.1*	*13.7*	*1.35*	*5.3*	*0*	*0*
HCFC-123	0	0	0	0	0	0	0	0	0	18	0	0	0	0
										0.36	-	-	-	-
HCFC-141b	90	340	510	410	440	585	621	447.1	538.8	609	360	102.3	20.3	13.4
	9.9	*37.4*	*56.1*	*45.1*	*48.4*	*64.3*	*68.3*	*49.2*	*59.3*	*66.99*	*39.6*	*11.3*	*2.23*	*1.47*
HCFC-142b	130	326	145	195	160	17	17	15.8	15.8	0	0	0	0	0
	8.45	*21.2*	*9.4*	*12.7*	*10.4*	*1.1*	*1.1*	*1*	*1*	*0*	-	-	-	-
Other HCFCs	0	0	0	5	<5	20	0	0	0	0	0	0	0	0
				n.s	*n.s*	*n.s*					-	-	-	-
HCFC-22 from HFC mixture										13.8	5.5	5.6	10.3	5.3
										0.76	*0.3*	*0.3*	*0.56*	*0.29*
HCFCs	1.203	1.479	1.410	1.302	1.215	1.222	1.172	1.029	901.6	889.9	390	204.7	142.7	114.3
ODP-weighted consumption	*73.65*	*103.3*	*106.7*	*98.9*	*92.3*	*98.4*	*98.8*	*81.3*	*79.4*	*81.45*	*41.25*	*16.9*	*2.79*	*1.76*
Total ODP-weighted consumption	*2,758*	*1,593*	*590*	*121*	*108*	*111*	*101.5*	*85.3*	*83.9*	*85.2*	*42.97*	*17.4*	*2.83*	*1.76*

1) Information from the Danish EPA environmental statistics.
n.i. = not informed n.s. = no specified information available for individual substances

Table 3.2 shows an overview of the Danish consumption of HCFCs by application area, based on information from importers and producers.

Table 3.2 HCFC consumption analysed by application area for 2005, based on information from importers and producers, tonnes.

Application area	HCFC-22	HCFC-123	HCFC-141b	HCFC-142b
System foam (for panels, insulation, etc.)	0	0	13.4	0
Refrigerants, New	0	0	0	0
Refrigerants, regenerated	95.6	0	0	0
Refrigerants, HFC mixtures	5.3	0	0	0
Total	100.9	0	13.4	0

3.1.7 Disposal

Denmark has two treatment facilities for destruction of ODSs - Kommune Kemi and Århus Genindvinding. All ODSs to be disposed are sent to these plants.

Kommune Kemi does not operate a registration system for individual substances because it receives and treats all substances in mixed tanks. Consequently, it is not possible to quantify the amounts of substances collected for treatment based on what the plant receives. Therefore, information from the importers that receive and send on used ODSs for treatment at the KK plant has been used instead.

Århus Genindvinding register the specific annual quantities of individual substances disposed at the facility.

The ODSs disposed in 2005 is shown in the table below.

Table 3.3 Disposed ODSs in 2005, tonnes.

ODS	Quantity, tonnes
HCFC-22	18.5
CFC-12	9.3
CFC-11	7.2

Some of the HCFC-22 originates from HFC blends (HFC-401a, HFC-402a, HFC-408a, HFC-409a) which are sent by Danish importers to Kommune Kemi for destruction.

4 Greenhouse gases

4.1 Import of substances

An overall picture of the trends in imports of greenhouse gases is given in Table 4.1, based on information from importers for the years 1987, 1989, 1992, 1994-2005.

4.1.1 HFCs

HFCs were imported by ten enterprises in 2005. Five of these end-users, are importing directly from other EU countries.

In 2005, the total import (minus re-export) of pure HFCs was 553.7 tonnes. When including import of R 413 and R 417 HFC blends, the total netto import of pure HFC's are 559.4 tonnes. Compared to 2004, when total consumption was around 711.5 tonnes, the import is decreased.. There are reductions for almost all HFCs. Only import of HFC-245 has increased.

The 2005 import of HFC-134a is reduced to 235.4 tonnes compared to 2004, where the import was 306.5 tonnes Further more is 5.05 tonnes HFC 134a imported in the blend refrigerant R413 blend (88% HFC-134a) and R417 blend (50% HFC-134a). The total reduction is coursed by lower consumption of producers of household refrigerators and commercial refrigeration system. Thus there has been a slight increase of the consumption of HFC-134a in aerosol spray and mobile A/C.

Imports of HFC-404a decreased from 252.6 tonnes in 2004 to 162.4 tonnes in 2005. This consumption indicate a step-back closer to the average level for the last decade and it is therefore assumed that the 2004 consumption of HFC-404 was extraordinary high and do not reflect a future trend, but reflect the difference in import over years. This is confirmed by comparisation of import with consumption data from KMO, where the consumption of HFC-404a has increased in 2005.

Imports of HFC-407c were reduced from 101.3 tonnes in 2004 to 61.6 tonnes in 2005. HFC-407c is a substitute refrigerant for HCFC-22 in refrigerators. Similar to HFC-404a, the 2004 consumption of HFC-407c was extraordinary high and seems not to reflect a future trend, but the difference in import over years. A comparison with consumption data from KMO shows a slight increase of the consumption of HFC-407c in 2005.

Imports of HFC-507a have been reduced to 5.4 tonnes in 2005. In 2004, imports were 10.6 tonnes.

The import of HFC-410a was 3.1 tonnes and the import of other HFC's and refrigerants containing HFC's (R413a, R417a) were netto 6.3 tonnes blend products where HFC's is part of the contents.

The import of HFC-152a used for foam blowing was 5.5 tonnes in 2005

There were no imports of HFC-401a and HFC-402a in 2005.

4.1.2 Sulphur hexafluoride

Four importers reported having imported and sold 3.58 tonnes of sulphur hexafluoride in 2005. Sulphur hexafluoride was used in power switches and in production of micro chips.

Use of SF_6 in other areas, are phased out. .

4.1.3 Per fluorinated hydrocarbons

There has been a minor import of per fluoro compound $C_3F_{8,}$, of 0.45 tonnes. The amount was contained in the blend refrigerant R413 used in commercial refrigerators.

Table 4.1 Developments in imports of greenhouse gases, tonnes.

Substance	1987	1989	1992	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
HFC-134a	0	0	20	524	565	740	700	884	644.	711.1	472.8	401.6	241.2	306.5	235.4
HFC-152a	0	0	4	51	47	32	15	14	6	16.4	11.1	11.9	3.3	11	5.5
HFC-401a	-	-	-	-	-	-	-	15	35.8	9.5	4.1	0	0.2	0	0
HFC-402a	-	-	-	-	-	-	-	10	15	4.2	0.8	0	1.7	0	0
HFC-404a	0	0	0	36	119	110	110	146	10	193.1	126.2	188.7	145	252.6	162.4
HFC-407c	-	-	-	-	-	-	-	17	193.7	44.7	40.3	89.1	96.8	101.3	61.6
HFC-507a	-	-	-	-	-	-	-	10	40	23.8	2.2	14.4	9.2	10.6	5.4
HFC-365	-	-	-	-	-	-	-	-	10	-	-	-	18	7.2	18.5
HCF-410 a	-	-	-	-	-	-	-	-	-	-	-	-	-	2.6	3.1
Other HFCs[1]	0	0	0	1	14	20	65	15 [1)]	29.2[1)]	24.1[1)]	18.4[1)]	7.5[2)]	13[2]	14,4	68.4
All HFCs	0	0	24	612	745	902	890	1112	978.3	1026.	676	713.2	528.3	706.2	560.3
Sulphur hexafluoride	n.i.	n.i.	15	21	17	11	13		12.1		4.7	1.4	2.2	2.34	3.58
Perfluorinated hydrocarbons	0	0	0	0	1.5	3	8		7.9	6.[illegible]	3.7	1.95	0.5	0.3	0.45

[1)] The category "other" includes R413a, R417a Isceon 79 and HFC-245fa, (in the emission calculation the emission factor for HFC-410a is used).

4.2 Consumption by sectors

The evaluation of consumption divided into sectors is estimated on the basis of information from importers and producers, and on sales reports to the Danish Refrigeration Installers' Environmental Scheme (KMO). Table 4.2 shows consumption distributed on sectors.

Table 4.2 Consumption of HFC distributed on sectors in 2005, tonnes.

	134a	152a	401a	402a	404a	407c	507a	410a	413a	417a	Others	Total from sectors
Insulation foam	0.8											0.8
Foam systems	0										64	64
Soft foam	11.9	0										11.9
Other applications	15	5.5										20.3
Household fridges/freezers	65.5				3.7							69.2
Commercial refrigerators	103.4		0	0	151.3		5.4	3.1	5.0	1.3	5.1	274.6
Transport refrigeration	0.5				7.4							7.9
Mobile A/C	33.3											33.3
Stationary A/C	5.0					61.6						66.6
Total	235.4	5.5	0	0	162.4	61.6	5.4	3.1	5.0	1.3	69.1	548.8

There are no other known sectors using HFCs in Denmark than those appearing in Table 4.2. Compared to recent years, the table specifies the consumption further into to the sub-sectors Mobile A/C, Stationary A/C.

4.2.1 Consumption of HFC refrigerant

In recent years, the Danish consumption of HFCs as refrigerants points toward increased use of HFCs in commercial refrigeration, but in 2005 the import has decreased for the first time. It indicates, that the consumption of HFC in commercial refrigerators is stabilizing and that the 2004 import was particularly high. Data from KMO shows an increase in the consumption for 2005. Therefor it is expected, that the reason for the divergence is a time lag in the import of HFC between 2004 and 2005.

The general increase in HFC refrigerants in commercial systems is a natural consequence of the phase-out of air conditioners based on R-22 (HCFC). More over, commercial refrigeration with R-12 and R-502 were replaced by R-22 systems after 1995 when CFCs were banned in Denmark. This added to the percentage of refrigeration systems with R-22. The production of new R-22 systems was prohibited in 2000 and substitution with R-22 in existing systems was prohibited in 2002.

The use of HFC's as refrigerant in commercial refrigeration and A/C systems is covering approx. 75 per cent of the total consumption in 2005. The most commonly used refrigerant in commercial refrigeration is still HFC-404a and HFC-134a. Approx. 18 per cent of the HFC consumption is used in foam blowing and for other purposes than refrigeration in 2005.

The consumption of HFC-134a as a refrigerant in fridges/freezers was again reduced in 2005 with approx. 20 tonnes.. The decrease is not considered as an indication of a general reduction in the production in the Danish refrigeration sector but an indication of that the sector has substituted to other alternatives.

The consumption of refrigerants in vans and lorries has increased in smaller scale and the consumption of refrigerants for mobile A/C systems have again increased this year.

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 figures for refrigerants in commercial and stationary A/C systems, and mobile A/C systems and refrigerators are estimated using data from KMO and information from importers as well as statistics on car imports.

Table 4.3 shows the relative consumption by weight of refrigerants according to application area.

Table 4.3 Consumption of refrigerants, divided on refrigeration units, 2005, tonnes.

Substance HFC	Fridges /freezers	Commercial refrigerators and A/C systems	Mobile A/C systems	Refrigerated vans and trucks	Total	In per cent
-134a	65.5	108.5	33.3	0.5	207.8	46.0%
-401a	-	-	-	-	-	0%
-402a	-	-	-	-	-	0%
-404a	3.7	151.3	-	7.4	162.4	36.0%
-407c	-	61.6	-	-	61.6	13.6%
-507a	-	5.4	-	-	5.4	1.2%
Others	-	14.5	-	-	14.5	3.2%
Total	69.2	341.3	33.3	7.9	451.7	100%
	15.3%	75.5%	7.4%	1.8%	100%	

4.2.2 Consumption of HFC as foam blowing agent and as propellant

In 2005, the consumption of HFC's in system foam has increased further but the consumption of HFC's used for foam blowing is reduced to approx. half the 2004 consumption.

It is considered that the general trend in the recent years is reduction of the HFC consumption as a blowing agent and this is the direct consequence of a statutory order on phase-out of potent industrial greenhouse gases, as well as the fact that there are competitive alternative technologies available on the market.

In 2005, the uses of HFCs as propellants in aerosols for specific purposes were about 15 tonnes. This estimate is based on DEPA's grant of exemptions and the consumption seems to be stable tending to an increase even though the statutatory order on phase out is in force..

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.

4.2.3 Consumption of SF_6

The overall consumption of SF_6 in 2005 was app. 3.58 tonnes. Consumption of SF_6 was used only for power switches in high-voltage power systems.

Table 4..4 Consumption of SF_6 by application area, tonnes

Application area	DK consumption, tonnes
Double-glazed windows	-
Power switches in high-voltage plants	3.58
Micro chip production	0
Total	3.58

4.2.4 Consumption of PFCs

The consumption of PFC's (per fluoropropane) in 2005 was 0.45 tonnes. The amount is contained in the blend refrigerant Isceon 49. Total consumption of PFC's for refrigeration purposes amounted to about 0.3 tonnes in 2004.

4.3 Emissions of F-gases: HFCs, PFCs and SF_6

This section reports the actual emissions of the greenhouse gases HFCs, PFCs, and SF_6 for 2005. The calculation is based on the reports on consumption of these substances analysed by application areas (section 4.2). For relevant product groups, adjustments have been made for imports and exports of the substances in products.

Appendix 5 shows the emission factors, calculation method and assumptions, IPPC Tier method etc., in relation to calculation of emissions from individual substance and application areas /4, 16/.

4.3.1 Actual emissions of F-gases

The GWP-weighted actual emissions of HFCs, PFCs, and SF_6 in 2005 is calculated to 839,5 thousand tonnes CO_2 equivalents. The corresponding emissions were approx. 796,8 thousand tonnes CO_2 equivalents in 2004, which corresponds to a calculated total increase of approx. 42,7 thousand tonnes CO_2 equivalents.

The total GWP contribution divided between HFCs, PFCs, and SF_6 is shown in the table below.

Table 4.5 GWP contribution by substance group, tonnes

Substance group	Consumption, tonnes 2004	Consumption, tonnes 2005	GWP contribution, tonnes 2004	GWP contribution, tonnes 2005
HFCs	711.4	559.6	747 800	803 900
PFCs	0.3	0.5	15 900	13 900
SF_6	2.3	3.6	34 000	21 700
Total			796 800	835 500

The HFC emission from HFC-404a and HFC-407c in commercial refrigerators were again significantly higher in 2005 as compared to 2004, partly because of increased emission from stock and partly because of a relatively large consumption. Furthermore the emissions of from both household- and commercial HCF-134a refrigerators have increased

4.3.2 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, lorries, buses, trains etc.)
- Refrigerated vans and lorries

Actual emissions from these sources occur in connection with:

- *filling* of refrigerants (0.5 per cent to 2 per cent of consumption depending on application area).
- *continual release* during the operational lifetime. An assumed average value which also accounts for release occurring as a result of accident and damage (10 per cent to 33 per cent of consumption per year, depending on application area).

Release resulting from *disposal* does not count as emissions in Denmark since Danish legislation ensures that management and treatment of refrigerants prevent such emissions. The release is defined in order to write down stock (the quantity of refrigerants contained in a product).

Appendix 5 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-404a, HFC-407c, and HFC-134a.

In addition, use of the refrigerants HFC-408a, HFC-409a, HFC-410a, and HFC-507c is less common, and HFC-401a and HFC-402a are phased out.

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

Table 4.6 shows actual emissions of specific HFCs. Total emissions of all HFCs have been converted to CO_2 equivalents in order to take into account the different GWP values of the substances.

Table 4.6 Actual emissions and GWP contribution from commercial refrigeration 2005 and 2010, tonnes

Commercial refrigeration and stationary A/C systems 1)					
Substance	Consumption, DK, 2005	Stock, 2005	Actual emissions, 2005	GWP contribution, 2005	GWP contribution 2010
HFC-134a	112.8	836.6	82.3	106 990	103 627
HFC-404a	151.3	1057.0	103.2	336 285	355 427
HFC-401a	0.0	16.3	2.0	36.6	0.0
HFC-402a	0.0	24.3	2.8	4 696	3 242
HFC-407c	61.6	378.6	36.2	55 280	60 621
HFC-507a	5.4	60.9	6.3	19 410	18 470
Other HFCs 2)	14.5	108.6	10.7	18 446	19 130
All substances				541 144	560 518

1) The projected future scenario takes into account the effect of a new statutory order on phasing-out HFCs etc. and the effect of the taxes implemented. Furthermore, assumptions about the substitution of HCFC-22 systems by HFC-134a and HFC-404a are included in the calculations.

2) The category "Other HFCs" includes HFC-408a, -409a and -410a (the calculation of emissions is based on a worst-case scenario on the basis of the GWP value of HFC-410a).

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 5).

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 per cent 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. The statistical background data for this is given in Appendix 2.

In addition, the effect of taxes on the reduction in consumption is taken into account in the future scenario of consumption of HFC-134a in fridges. These taxes are assumed to lead to a gradual reduction in consumption. This is assumed not to be the case for HFC-404a-based household refrigerators/freezers since these are special products.

Table 4.7 shows actual emissions from refrigerators/freezers in 2005 and 2010.

Table 4.7 Emissions of refrigerants from refrigerators/freezers 2005 and 2010, tonnes

	HFC-134a		HFC-404a	
	2005	2010	2005	2010
Consumption	65.5	65.5	3.7	3.7
Emissions during production	1.3	1.3	0.1	0.1
Exports	32.8	32.8	0.0	0.0
Stock	820.7	887.4	79.8	91.5
Emission from stock	8.0	8.9	0.8	2.7
Emissions during destruction	0.0	0.0	0.0	0.0
Actual emissions	9.3	10.2	0.9	1.1
GWP contribution, 1000 tonnes CO2 equivalents	12.1	13.2	2.9	3.5

Total emissions of HFC-134a and HFC-404a refrigerants from refrigerators/freezers in 2005 were approx. 14 900 tonnes CO_2 equivalents. In the future scenario of actual emissions, a slight increase in the emission is expected. The total in 2010 is estimated to 16.700 tonnes CO_2 equivalents.

Mobile A/C

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

The calculation has been adjusted for imports and re-exports of HFC-134a, which is the only HFC imported in A/C systems in cars and lorries. In Denmark, 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.

The assumptions used in the calculation of consumption and stock in mobile A/C systems appear from the table below. The assumptions have been adjusted according to individual statistical categories for types of transport and they represent estimated values based on information from car importers and refrigerator service enterprises /16/.

Table 4.8 Assumptions used in the calculation of stock in mobile A/C systems, 2005

	Proportion with A/C, %	Filling, kg HFC-134a	Percentage of all vehicles that undergo A/C maintenance
Cars	10 %	0.75	50 %
Busses	20 %	9	20 %
Vans	10 %	0.8	50 %
Trucks	50 %	1.5	40 %

D.A.F. (The Danish Automobile Dealers Association) publishes annual statistics of the number of vehicles in Denmark /17/. These data form the basis for the calculation below of HFC-134a stock in Danish vehicles. Calculations also include a calculation of the proportion of A/C systems installed in vehicles, which are still undergoing servicing, and which are therefore still being refilled with refrigerants in connection with leakage and other repairs. This calculation forms the basis for determining the amount of HFC-134a refrigerants refilled in vehicles in Denmark in 2005. Refilled stock = Danish consumption.

The results are shown in the table below.

Table 4.9 Determination of Danish stock in mobile A/C systems in 2005, tonnes

	2005	Stock, kg, tonnes	Maintenance, filling, tonnes	Average filling per year, tonnes HFC-134a
Private cars	1960563	147.0	73.5	24.5
Busses	8977	16.2	3.2	1.1
Vans	420828	16.8	8.4	2.8
Trucks	49319	37.0	14.8	4.9
SUM		217.0	100.0	33.3

The total stock of HFC-134a in mobile A/C systems in Denmark in 2005 was calculated to be about 217 tonnes, which are a further increase compared to 2004 stock.. In 2005, the volume of HFC-134a filled onto mobile air conditioning systems was 33,3 tonnes. This volume of refrigerants was used solely for refilling in connection with the maintenance of existing systems /16/. It is indicated from suppliers of mobile A/C refrigerants, that the consumption is even higher than this estimated. One supplier expect the consumption to be approx. 40 tonnes of HFC-134a per. year.

The table below shows a projection of calculated actual emissions from mobile A/C systems in Denmark. The table has been prepared on the basis of a steady-state assumption where imports and consumption for refilling in 2010 are assumed to be almost the same as in 2005.

Table 4.10 The calculated actual emissions of HFC-134a from mobile A/C systems in 2005 and 2010, tonnes

	2005	2010
Imports via automobiles	27.8	27.8
Consumption to refill	33.3	38.3
Total stock increase	61.1	66.1
Emissions from filling	1.5	1.7
Emissions from stock	63.4	66.3
Total emission	64.9	68.0
Stock	213.0	223.0
Actual emissions	64.9	68.0
GWP contribution, 1000 tonnes CO_2 equivalents	84.3	88.4

Refrigerated vans and lorries

There are an estimated 5 500-6 000 refrigerated vans and lorries in Denmark /16/. These require an average filling of about 8 kg, equivalent to 46-49 tonnes refrigerants, either HFC-134a, HFC-404a or HCFC-22.

Actual emissions from refrigerated vans and lorries in 2005 are stated in the table below.

Table 4.11 The calculated actual emissions of HFC-134a and HFC-404a from refrigerated vans and lorries in 2005 and 2010, tonnes.

	HFC-134a		HFC-404a	
	2005	2010	2005	2010
Consumption	0.5	0.5	7.4	7.4
Emissions from filling	0.0	0.0	0.4	0.4
Contribution to stock	0.5	0.5	7.1	7.1
Emissions from Stock	1.1	0.7	5.4	6.4
Stock	5.7	3.9	33.6	38.5
Actual emissions	1.1	0.7	5.8	6.8
GWP contribution, 1000 tonnes CO2 equivalents	1.4	1.0	19.0	22.2

There was no consumption of HFC-402a for refrigerated vans and lorries since the substance has now been phased out. But the emission from stock is about 0.3 tonnes from HFC-402a, corresponding to 500 tonnes CO_2 equivalents.

Thus, the total actual emissions from refrigerated vans and lorries were app. 20 900 tonnes CO_2 equivalents in 2005.

4.3.3 Emissions of HFCs from foam plastic products and propellants

Two calculation principles have been applied in the calculation of emissions of HFCs used in 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 following basis of calculation has been used in the emissions calculation for foam plastic products.

Table 4.12 Factors in the calculation of emissions from foam plastic products

	Hard PUR foam	Soft PUR foam	Polyether foam
Release during production	10%	100%	15%
Annual loss	4.5%	-	4.5%
Lifetime	15	-	1-10 (3 years)

Insulation foam

Hard foam plastic produced with HFC-134a is used primarily in insulating foam for refrigerators/freezers. Calculations of emissions from insulating foam in refrigerators/freezers have been adjusted for imports and exports of fridges/freezers.

Consumption of HFC-134a for foaming of insulation foam used in fridges/freezers was phased out in 2003. Actual emissions are therefore solely from stock and there are no longer any exports.

Actual emissions of HFC-134a from insulating foam are summarised in Table 4.13

Table 4.13 Emissions of HFCs from insulating foam, tonnes

	2005	2010
Consumption, HFC-134a	0.8	0.0
Emissions during production	0.1	0.0
Exports	0.0	0.0
Stock	1225.9	757.5
Emission from stock	78.1	66.7
Actual emissions	78.2	66.7
GWP contribution, 1000 tonnes of CO_2 equivalents	101.7	86.7

In the projections for 2010, it is estimated that the stock will be reduced as a result of the phase-out of HFC-134a as blowing agent. Previous projections estimated a phase-out by 2006. However, it is a fact that this blowing agent had already been phased out in Denmark and the latest consumption from the sector was reported in 2003.

Foam blowing of Polyether based shoe soles

The consumption of HFC-134a used in polyether-based foam blowing in DK production of shoe soles is expected out-phased in 2005.

Statistical calculations from 1998 are used as the 2005 import estimate. The import of HFC-134a is 5,1 tonnes. In the calculation, it is estimated that 5 per cent of all shoes with plastic, rubber, or leather soles contain polyether foam blowed with HFC-134a . In 1998 about 12.8 million pairs of shoes were imported (Statistics Denmark's foreign trade statistics) and it is estimated that a single pair of shoes contains an average of 8g HFC-134a.

Soft foam/aerosol sprays.

Emissions from soft foam (open cell foam) account for 100 per cent of the consumption in the year of application /4/. Emissions from soft foam occur during production and it is therefore not relevant to adjust for imports/exports.

The emission of HFC in the production of *soft foam* is identical to the consumption in Denmark, and the emission of HFC as a propellant in aerosol sprays is also equal to the consumption of HFC-based aerosol sprays in Denmark, after calculation of imports and exports. Total emissions from these two areas amount to 26.9 tonnes of HFC-134a, corresponding to 29 100 tonnes CO_2 equivalents. Compared with 2004, emissions have been decreased by approx.18 000 tonnes of CO_2 equivalents. The reason is a major reduction in use of HFC-134a in soft foam blowing. The emission from aerosols has increased with approx. 5 100 tonnes of CO_2 equivalents.

Medical products

The emissions from medical products are marginal and have not been calculated.

4.3.4 Emissions of sulphur hexafluoride

The total emissions of SF_6 in 2005 have been calculated to 0.9 tonnes, equivalent to a GWP contribution of about 21,750 tonnes CO_2 equivalents. Net consumption was 3.6 tonnes.

Emissions derive from two sources - power switches and double-glazed windows.

Double-glazed windows
Use of SF_6 in double-glazed windows was phased out in 2002, however, there are still emissions from existing double-glazed windows in Danish buildings.

Table 4.14 Emissions of SF_6 from double-glazed windows, tonnes

	2005	2010	2015
Consumption	0.0	0.0	0.0
Emissions from production	0.0	0.0	0.0
Release from fitted double-glazed windows	0,4	0,4	0.2
Exports	0.0	0.0	0.0
Disposal emissions	0.0	0.0	3.7
Stock	38.3	36.4	18.4
Actual emissions	0.4	0.4	4.0
GWP contribution, 1000 tonnes CO_2 equivalents	9.3	8.8	94.5

Emissions will rise due to the disposal of existing double-glazed windows containing SF_6 and the estimated 2015 GWP contribution from double-glazed windows is still app. 95 000 tonnes CO_2 equivalents.

Power switches in high-voltage plants

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

Emissions from power switches in high-voltage transmission systems are released due to the following:

- 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)

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 company 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 4.15 shows the calculated actual emissions from SF_6 power switches.

Table 4.15 Emissions of SF_6 from power switches in high-voltage plants 2005, 2010, and 2015, tonnes.

	2005	2010	2015
Consumption	3.6	3.0	3.0
Service emissions	0.2	0.2	0.2
Recycling/recovery emissions	0.0	0.0	0.0
Emissions from stock	0.3	0.4	0.4
Stock	67.9	80.2	92.2
Actual emissions	0.5	0.6	0.6
GWP contribution, 1000 tonnes of CO_2 equivalents	12.5	13.4	14.8

At the request of the Danish Energy Authority, Eltra and Elkraft System have carried out a survey of SF_6 emissions during operation and following from accidents in 2003 /20/. This survey covers about 1/9 of the stock in the Danish electricity sector. Emissions have been calculated at about 20 kg of SF_6. Additionally, there are 88 kg of contaminated SF_6 in depot, and about 1.1 tonnes of new gas in store.

If this data is assumed to be representative of the entire country, emissions in 2003 amount to about 180 kg. This is under half of the calculated emissions of 0.5 tonnes in this emission calculation of 2005.

On the basis of Eltra's survey, the applied evaluation method is still considered to provide a true picture of total emissions. The difference in figures is explained by the fact that the calculation method does not take account of the time delay, so that SF_6 is assumed to be both purchased and consumed within the year of calculation. The notes from Eltra state that there is about 1.1 tonnes in store, which upon later use will lead to emissions. Further, more emissions are assumed to occur from the recycling or destruction of the 88 kg of contaminated gas in depot. If these emissions were actual emissions in 2003, it would mean emissions from Eltra and Elkraft System of about 80 kg of SF_6, and about 0.7 tonnes of SF_6 respectively, providing the data is representative for national level.

Laboratory purposes

Consumption of SF6 in laboratories covers two purposes:

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

Consumption was 0 tonnes in 2005.

Training shoes

In the period 1990 to 1998, Denmark imported training shoes, which, according to the manufacturer, contained SF_6. It is assessed that emissions of SF_6 from training shoes will not occur after 2003, while it is assumed that all shoes containing SF_6 is disposed by then.

4.3.5 Emissions of per fluorinated hydrocarbons

In 2005, the consumption of perfluorinated hydrocarbons (per fluoropropane), which are used exclusively in the refrigerant R413a, was 0.5 tonnes. The actual GWP-weighted emission is 13 900 tonnes CO_2 equivalents, which is a further reduction compared to 2004, 2003 and 2002.

Per fluoropropane is the only known per fluorinated hydrocarbon used in Denmark. Emissions are released from refrigerants in commercial stationary and mobile refrigerators. Stock in commercial refrigerators has been estimated at about 17.6 tonnes in 2005. While the refrigerants containing PFC are only used in stationary refrigerators, no estimates for imports and exports are relevant.

Table 4.16 Emissions of PFCs from commercial refrigerators in 2004, 2010 and 2015, tonnes

	2005	2010	2015
Consumption	0.5	0.9	0.6
Consumption	0.0	0.0	0.0
Emissions from stock	2.0	1.3	1.0
Stock	17.6	12.9	9.9
Actual emissions	2.0	1.3	1.1
GWP contribution, 1000 tonnes CO_2 equivalents	13.9	9.4	7.4

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ODP values for ozone-depleting substances and GWP values for F-gases

Table 1.a Ozone-depleting substances, their chemical formulas and Ozone Depleting Potential (ODP) - Regulated by the Montreal Protocol.

Substance	Chemical formula	ODP values
CFCs		
CFC-11	$CFCl_3$	1.0
CFC-12	CF_2Cl_2	1.0
CFC-113	$C_2F_3Cl_3$	0.8
CFC-115	C_2F_5Cl	0.6
Other CFCs	-	-
Tetrachloromethane	CCl_4	1.1
1,1,1-Trichloroethane	CH_3CCl_3	0.1
Halons		
Halon-1301	CF_3Br	10
Halon-1211	CF_2BrCl	3
Halon-2402	CF_2BrCF_2Br	6
Methylbromide	CH_3Br	0.6
HCFCs		
HCFC-22	CHF_2Cl	0.055
HCFC-123	$C_2HCL_2F_3$	0.02
HCFC-141 b	$C_2H_3FCl_2$	0.11
HCFC-142 b	$C_2H_3F_2Cl$	0.065
	-	

Table 1.b
F-gases, their chemical formulas and GWP values stipulated in the Kyoto Protocol

Substance	Chemical formula	GWP value
HFCs		
HFC-32	CH_2FH_2	650
HFC-125	C_2HF5	2,800
HFC-134a	CF_3CFH_2	1,300
HFC-143a	$C_2H_3F_3$	3,800
HFC-152a	CF_2HCH_3	140
HFC-245		950
HFC-227	C3HF7	2,900
HFC-365		890
HFC-404 a[(2)]	-	3,260
HFC-401a[(3)]	-	18
HFC-402a[(4)]		1,680
HFC-407c[(5)]		1,525
HFC-408a[(6)]		1,030
HFC-409a[(7)]		0
HFC-410a[(8)]		1,725
HFC-507a[(9)]		3,300
Sulphurhexafluoride	SF_6	23,900
Perfluorinated hydrocarbons		
Tetrafluoromethane (perfluoromethane)	CF_4	6,500
Fluoroethane	C_2F_6	9,200
(perfluoroethane)	C_3F_8	7,000
Fluoropropane	$C\text{-}C_4F_8$	8,700
(perfluoropropane)		
Fluorocyclobutane (perfluorocyclobutane)	C_6F_{14}	7,400
Fluorohexane (perfluorohexane)		

(1) No ozone-depleting effect.
(2) Mixture consisting of 52 % HFC-143a, 44 % HFC-125 and 4 % HFC-134a. The GWP value is determined from this.
(3) Mixture consisting of 53 % HCFC-22, 13 % HFC-152a and 34 % HCFC-124. The GWP value is determined from this.
(4) Mixture consisting of 38 % HCFC-22, 60 % HFC-125 and 2 % propane. The GWP value is determined from this.
(5) Mixture consisting of 25 % HFC-125, 52 % HFC-134a, and 23 % HFC-32. The GWP value is determined from this.
(6) Mixture consisting of 46 % HFC-143a and 7 % HFC-125. The GWP value is determined from this.
(7) 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.
(8) Mixture consisting of 50 % HFC-32 and 50 % HFC-125
(9) Mixture consisting of 50 % HFC-125, 50 % HFC-143a. The GWP value is determined from this.

Statistical data for calculations of imports/exports of fridges/freezers and mobile A/C systems

Table 1. Key figures for the content of HFC-134 in insulation foam and as a refrigerant per unit for calculation of imports and exports of fridges and freezers

Key figures	HFC-134a in insulation foam, g	HFC 134a refrigerant, g	HFC-134a, g/unit total
Fridge/ freezer	240	111	351
Fridges and freezers	240	65	305
Chest freezers	240	164	404
Cupboard freezers	240	127	367

Table 2. Imports and exports of HFC-134a calculated as net exports of fridges and freezers (source: Statistics Denmark's foreign trade statistics)

Exports, pcs	1998	1997	1996	1995	1994	1993	1992
Fridge/ freezer	26,387	65,491	40,040	48,332	47,851	72,017	66,488
Fridges and freezers	-109,550	4,308	-30,381	-90,011	-29,184	-11,382	-7,250
Chest freezers	815,523	778,580	701,748	879,172	855,691	771,198	766,453
Cupboard freezers	89,878	135,376	56,385	72,232	68,278	80,312	92,278
Exports, total units	822,238	983,755	767,792	909,725	942,636	912,145	917,969
Exports of foam (a16 chest freezers)	6,715	205,175	66,044	30,553	86,945	140,947	151,516
Total exports of HFC-134a, tonnes	338.3	388.5	309.0	371.2	372.4	90.7	0.0
HFC-134a (foam)	197.3	236.1	184.3	218.3	169.7	54.7	
HFC 134a (fridges)	141.0	152.4	124.7	152.9	202.7	36.0	
HFC-134a (foam, exports)	1.6	49.2	15.9	7.3	20.9	33.8	36.4

It should be noted that this is a considerable simplification since the quantity of HFC used for foam and refrigerant varies, depending on the producer and product size. The average quantities used are shown in Table 2.

Table 3. Statistical data on imports and exports of cars and lorries

Air conditioning	Cars	Lorries	Total, tonnes
Net imports, 1998	151 385	26 249	
Proportion with A/C	15 138.5	13 124.5	
Quantity HFC-134a, kg	11 353 875	16 405 625	27.8

Cars: 10% with A/C and 0.75 kg - 134a
Lorries: 50% with A/C and 1.25 kg - 134a

Consumption and emissions of ozone-depleting substances in Greenland

Statistics Denmark registers both imports to Greenland and exports from Denmark to Greenland.

The trends in supply of ODSs (only substances with position numbers in Statistics Denmark's foreign trade information) 1990-2005 are shown in Table 1.

Table 1. Trends in supply to Greenland based on data from Statistics Denmark, tonnes

Substance	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
CFC-11	5.5	0.1	4.5	0	2.2	1.6	0	0	2.1	1.9	<0.3	0	0.4	4.0	4.3	10.8
CFC-12	6.0	0	0.1	0	0.7	6.7	10.3	0	1.2	0	0	0	0	0	0	0
CFC-113	-	-	-	-	-	-	-	-	0	0	<0.2	0	0	0	0	4.5
CFC-115	-	-	-	31	5.5	0	0	0.2	0.4	0	0	0	0	0	0	0
All CFCs	13	7	6	31	8	8	10	0.2	3.7	1.9	<0.5	0	0.4	4.0	4.3	15.3
HCFC-22	-	-	-	-	-	-	-	-	-	-	-	20	4.6	6.8	14.8	-
1,1,1,- tri-chloroethane	-	-	-	-	-	-	-	-	-	-	-	-	0.08	0	0	0

Based on the statistics available it was not possible to evaluate the consumption of substances other than those shown in the table.

In 2005, Greenland imported 10.8 tonnes CFC-11 and 4.5 tonnes of CFC-113 from Denmark (Statistics Denmark).

The import of HCFC-22 in Greenland was not possible to determine from Statistic Denmark data. But the general export of new R-22 from Danish suppliers has increased as a whole, and it is expected that export to Greenland also has increased.

No reports of import/exports of 1,1,1-trichloroethane were recorded in 2005.

From the above data, ODP-weighted consumption in Greenland for 2005 was 14.4 ODP tonnes. This is an increase compared to 2004, where the ODP consumption was 5.11 tonnes ODP tonnes. Greenlands ODP weigthed emission is more than 14 times higher than the total Danish 2005 emission.

GWP contribution from HFCs, PFCs, and SF_6, 1993-2020.

The table below shows projections of determined GWP contributions.

The emission projections are determined by starting with a ‘steady state’ consumption using 2005 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. A tax effect is also included in the relevant areas of application and expected increases in several applications and sectors are taken into account as much as possible, as are expected reductions in several of the application areas. However, scenarios of the consumption of HFC-404a in the emission calculations are based on conservative developments. The phasing out of HCFC-22 refrigerating plants is expected to lead to greater increases in the consumption of HFC-404a in commercial refrigerating plants than was presupposed, since HFC-404a together with CO2 units are the most obvious substitution possibilities. From 1 January 2000, it is prohibited to build new HCFC-22 systems, and from 1 January 2002, it is prohibited to substitute with new HCFC-22 in existing refrigerators.

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

Table 1. GWP contribution from HFCs, PFCs, and SF_6 in 1000 tonnes, 1993-2020

	HFC-134a	HFC-152a	HFC-404a	HFC-401a	HFC-402	HFC-407c	HFC-507a	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	290.5	5.3	176.8	0.1	8.7	5.4	5.7	10.2	12.5	65.4	580.5
2000	318.6	2.3	239.6	0.1	9.5	11.0	8.9	14.1	17.9	59.2	681.2
2001	338.2	1.8	236.8	0.1	9.0	16.6	14.3	29.4	22.1	30.4	698.9
2002	350.8	1.8	256.5	0.1	8.0	22.2	14.2	17.5	22.2	25.5	718.8
2003	329.2	0.2	290.0	0.1	7.0	33.8	17.0	17.2	19.3	31.9	745.6
2004	346.9	0.8	312.7	0.0	6.1	45.3	18.2	17.8	15.9	33.1	796.8
2005	347.2	0.2	358.1	0.0	5.2	55.3	19.4	18.4	13.9	21.8	839.5
2006	331.7	0.2	374.8	0.0	4.5	59.1	19.1	19.1	12.4	22.2	843.3
2007	335.5	0.3	388.2	0.0	3.9	62.1	18.9	19.6	11.0	22.4	862.0
2008	336.0	0.3	391.3	0.0	3.7	62.0	18.9	19.6	10.3	22.6	864.7
2009	324.2	0.3	388.3	0.0	3.6	61.0	18.6	19.3	9.8	22.8	847.9
2010	312.4	0.3	381.1	0.0	3.4	60.6	18.5	19.1	9.4	23.0	827.9
2011	303.8	0.3	344.5	0.0	3.3	60.2	18.4	16.6	9.1	55.4	811.6
2012	273.7	0.4	315.3	0.0	3.1	59.8	18.2	13.2	8.7	101.5	793.9
2013	260.3	0.4	290.4	0.0	3.0	57.3	15.6	10.9	8.3	111.4	757.5
2014	217.8	0.4	258.2	0.0	2.8	54.5	12.6	8.9	7.9	124.0	687.1
2015	196.9	0.4	216.9	0.0	2.6	48.4	9.9	4.8	7.4	109.3	596.6
2016	170.9	0.4	175.7	0.0	2.4	42.2	3.2	1.9	7.0	81.6	485.2
2017	153.9	0.4	146.1	0.0	2.1	33.7	3.6	0.5	6.6	66.6	413.7
2018	139.5	0.5	99.0	0.0	1.9	18.9	0.1	0.9	6.2	96.6	363.7
2019	137.2	0.5	75.4	0.0	1.7	5.3	0.0	0.3	5.9	65.9	292.2
2020	126.2	0.5	21.1	0.0	1.5	0.0	0.0	0.0	5.7	45.4	200.4
Total	7110	42	6011	1	116	878	277	297	265	1762	16758.7

Specification of methods and assumptions for determination of emissions for 1990-2003 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	0.5% on refilling (DK default) 33% annual release during operation (complete refilling every 3 years - DK default).	In 2001/2002 an assessment was made of the national Danish leakage rate from mobile A/C systems. This	The projection is based on a steady state stock (203 tons).

ID	Source	Substance	Methods	Emission factor	Remarks	Projection assumptions
			used for gathering of consumption data from importers for refilling of mobile A/C systems.	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). 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).	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 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	

ID	Source	Substance	Methods	Emission factor	Remarks	Projection assumptions
					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.	
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	

ID	Source	Substance	Methods	Emission factor	Remarks	Projection assumptions
					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					
	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.	
	MDI (metered dose inhalers)	HFC-134a	Tier 2 bottom-up approach - consumption was studied in 1999 and was evaluated as minimal.			Due to minimal emissions, this class of products is no longer included in Denmark's national inventory.
	Solvents					
R1	Liquid cleaners	PFC (C_3F_8 Perfluorpropane)	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.
	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	Emission (DK-default): - 15% during production of double glazing. - 1 % per year during the lifetime of the window		Emissions data and lifetimes are based on information from the window producers and industry experts in Denmark /2/.

ID	Source	Substance	Methods	Emission factor	Remarks	Projection assumptions
			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.	- 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		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

ID	Source	Substance	Methods	Emission factor	Remarks	Projection assumptions
						per year in the period 2004-2010.

Assessment of Good Practice Guidance compliance in DK F-gas calculation 2005

The Danish F-gas emissions are calculated for the historical years up to 2005. 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% of total emission 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.

Emission of substitutes from ODS – decision tree figure 3.11

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 to the F-gas emission report 2005 (Environmental Protection Agency, 2006), 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 manufactur. 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 aircondition 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. This is particularly important for the ODS substitutes sub-sectors because of the large populations of equipment and products.

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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