Notater
Documents
24/2013

Statistics Norway

Statistisk sentralbyrå

Kathrine Loe Bjønness

Emissions of HFCs and PFCs from product use in Norway

Documentation of methodologies

Documents 24/2013

Kathrine Loe Bjønness

Emissions of HFCs and PFCs from product use in Norway

Documentation of methodologies

Statistisk sentralbyrå • Statistics Norway
Oslo–Kongsvinger

Documents In this series, documentation, method descriptions, model descriptions and standards are published.

Published June 2013

ISBN 978-82-537-8685-8 (printed)
ISBN 978-82-537-8686-5 (electronic)
ISSN 1891-5906
Subject: Nature and environment

Print: Statistics Norway

Symbols in tables	Symbol
Category not applicable	.
Data not available	..
Data not yet available	…
Not for publication	:
Nil	-
Less than 0.5 of unit employed	0
Less than 0.05 of unit employed	0.0
Provisional or preliminary figure	*
Break in the homogeneity of a vertical series	—
Break in the homogeneity of a horizontal series	|
Decimal punctuation mark	.

Preface

This report documents the revised methodology used to estimate emissions of fluorinated substitutes for ozone depleting substances in the Norwegian emission inventory from 2013 (reference year 2011) and onwards. This comprises emissions of hydrofluorocarbons and perfluorocarbons when used in products such as refrigeration and air conditioning equipment. It does not include emissions of fluorinated substances when generated as a by-product in for instance aluminium production.

The methodology was used for recalculating emissions for earlier years as well, starting in 1990, and the whole time series estimated according to the revised methodology is now a part of the annually published Norwegian statistics on emissions of greenhouse gases (http://www.ssb.no/english/subjects/01/04/10/klimagassn_en/). It is also part of the annual reporting to the UNFCCC by the Norwegian Climate and Pollution Agency (Klif), under the convention of climate change.

The report focuses on giving thorough descriptions of methodology and data sources. However, a short description of the resulting emissions and the differences between emissions as calculated with revised and original methodology is also provided. Tables containing detailed information on activity data and emissions can be found on http://unfccc.int, under National Reports and GHG data.

Information about the original methodology and activity data, which were used in the emission inventory prior to 2013, can be found in the following two reports:
- Haukås et al. (1999): "Calculations of emissions of HFCs and PFCs in Norway"
- Hansen (2007): "Emissions from consumption of HFCs, PFCs and SF6 in Norway"

The work with this report was carried out with financial support from The Norwegian Climate and Pollution Agency. The project was run by Kathrine Loe Bjønness, in close cooperation with Håkon Frøysa Skullerud and with contributions from Marte Kittilsen, Ketil Flugsrud, Nina Holmengen, Eilev Gjerald (Klif) and Torgrim Asphjell (Klif).

Statistisk sentralbyrå, 30 .mai 2013

Hans Henrik Scheel

Abstract

Emissions of hydrofluorocarbons (HFC) and perfluorocarbons (PFC) from use in products are included in the Norwegian statistics on greenhouse gases and reported by the Norwegian Climate and Pollution Agency (Klif) to the UNFCCC. A project was started by Statistics Norway in 2011, with funding from Klif, in order to include a new data source in the calculations. The project also aimed to update activity data, emission factors and the calculation methodology and tools.

The Norwegian emissions of HFCs and PFCs from product use, as estimated in this project, amounted to 950 000 tonnes CO_2-equivalents in 2011. This emission source is hence responsible for less than 2 per cent of the total Norwegian emissions of greenhouse gases. The emissions are assumed to have started around 1990 and have increased mainly because of the imports and use of three HFCs: HFC-125, HFC-134a and HFC-143a. The imports of HFCs for use in refrigeration equipment have seized to increase and even decreased the last few years. This is probably due to the taxation on these chemicals. Imports and use of HFCs in mobile and stationary air conditioning equipments is however still increasing.

The new data source, the Norwegian Directorate of Customs and Exice (TAD), provides annual data on imports of HFCs and PFCs. This data source was mainly used for providing data for 2010-2011, but it was also used for updating activity data for the years 1990-2009. For the years previous to 2010, a time series has been constructed based on a combination of data sources: a query sent to major importers asking for information for the years 1995-1997 and reported amounts of chemicals in bulk to Klif. Exports of HFCs and PFCs are limited and of little importance to the emission estimates. The data are estimated annually based on information from the previously named data sources. Annual data on collection and destruction of HFCs and PFCs has been reported by Stiftelsen returgass for all relevant years (i.e. from 2004).

The starting point for the emission calculations is to determine the amount of chemicals in equipment and bulk respectively being available for use in each relevant application category for each year. The use of HFCs and PFCs in products is assumed to have begun in 1990. The following application categories are considered in the model: domestic refrigeration, commercial refrigeration (stand-alone applications and larger refrigeration systems), transport and industrial refrigeration, stationary and mobile air conditioning, soft and hard foam products, fire protection (portable and fixed flooding systems), aerosols (metered dose inhalators and other) and solvents.

The next step in the calculations is to estimate the amount of chemicals in new equipment, the amount used for production of new equipment, and the amount in retired equipment. The amounts are estimated for each year, application category and type of chemical. Emission factors specific to each applications category are then applied to these amounts in order to estimate emissions, with one exception: emissions from use of mobile air conditioning are determined to be no less than the amount of chemicals imported in bulk, based on a mass balance approach. The amount accumulated in equipment in use is calculated for control purposes.

The updating of activity data, emission factors and methodology, resulted in higher level of emissions for almost all years in the period 1990-2011. This is an effect of change in emission factors (lifetimes) and methodology. Over time, however, the emissions will actually have decreased because of decreasing total imports in the updated activity data.

Contents

1. Introduction

Hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) are synthetic chemicals with properties making them suitable for a variety of application areas: They are in general chemically and thermally stable molecules with low flammability, and they are not very corrosive, explosive or poisonous. Nowadays they are widely used in refrigeration and air conditioning equipment, in production of construction materials like insulation mats, as solvents and aerosols.

The use of HFCs and PFCs in products was very limited 20 years ago. Other fluorinated substances like chlorofluorocarbon (CFC) and hydro chlorofluorocarbons (HCFC) were then dominating these application areas. After realising that CFCs and HCFCs were damaging to the ozone layer, they were regulated under the Montreal protocol. The Montreal protocol has led to a gradual phasing out of these substances, and HFCs and PFCs are phased in as substitutes. All imports and exports of CFCs and HCFCs were banned from the 1st of January 2010.

The substitutes (HFCs and PFCs) are, as the CFCs and HCFCs, potent greenhouse gases. Hence they have been included amongst the greenhouse gases to be reported to the UNFCCC under the Kyoto protocol. The most commonly used chemical, HFC-134a, is about 1 300 times more potent than CO_2. Table 1.1 lists the chemicals included in this study and their Global Warming Potential (GWP) values.

The increased use of HFCs and PFCs has been met by the Norwegian government by a tax on imports and production of these chemicals. The tax was introduced in 2003, and in 2004 it was supplemented with a refund system for destruction of used chemicals. Both tax and refund was in 2013 about 230 NOK (30 Euros) per tonne of CO_2 equivalents. There is no production of HFCs or PFCs in Norway.

Table 1.1. Common HFCs and PFCs, and their GWP-values

Chemical	GWP-value
Hydrofluorocarbons (HFC)	
HFC-23	11 700
HFC-32	650
HFC-125	2 800
HFC-134	1 000
HFC-134a	1 300
HFC-143	300
HFC-143a	3 800
HFC-152a	140
HFC-227ea	2 900
Perfluorocarbons (PFC)	
PFC-218 (C_3F_8)	7 000

1.1. Background

A new data source that became available, containing detailed information about imports of HFCs and PFCs, was the starting point for the work described in this report.

Up to 2009, Statistics Norway received annual data on imports and exports of HFCs and PFCs in bulk from The Norwegian Climate and Pollution Agency (Klif). This data source has been of major importance to the emission calculations and is described in chapter 3 of this report. From 2003, similar data became available through the Norwegian Directorate of Customs and Excise (TAD), and in 2009 the data collection by Klif was closed down. The **primary goal of this project was therefore to establish a system for collection and adaption of the data from TAD** and thereby securing the annual calculation and reporting of emissions of HFCs and PFCs to the UNFCCC.

In addition, the calculation model set up in 1998 needed to be upgraded in several ways. In order to improve transparency and provide the UNFCCC with adequate data, it was necessary to make changes to the application categories used in the calculations, and activity data and emissions from disposal were to be made available for reporting. Disposal data were previously reported as a part of operating stocks, and this was not in line with reporting requirements. A slight overestimation of emissions were also to be corrected, by the incorporation of data on destruction of used gas and by removing the requirement set by the model that a gas has to be imported every subsequent year after it was first imported. The latter was purely an artefact of the previous model, and was not founded in true usage of HFCs and PFCs.

The calculation process, i.e. the data flow from input to output, needed to be streamlined, both for the dissemination of statistics and for reporting to the UNFCCC.

2. Methodology

The Norwegian emissions of HFC's and PFC's are estimated according to the methodology recommended and described in the revised 1996 IPCC Guidelines (IPCC 1997). They are however also in line with the recommendations given in IPCC Guidelines from 2006. In general, emissions from a product a certain year can be calculated by multiplying the amount of chemical in the product (also called application), by an emission factor reflecting the leakage rate from that specific product.

$$E_{y,a,c} = A_{y,a,c} \cdot EF_a$$

$E = Emission$
$A = Activity\ data$
$EF = Emission\ Factor$
$y = year$
$a = application$
$c = chemical$

The emission factors used in the Norwegian emission estimates are within the range recommended in IPCC (1997), and set by national experts based on their knowledge about Norwegian equipment and conditions (Haukås et al. 1999). The emission factors are listed in Table 2.1.

Table 2.1. Emission factors for HFCs and PFCs

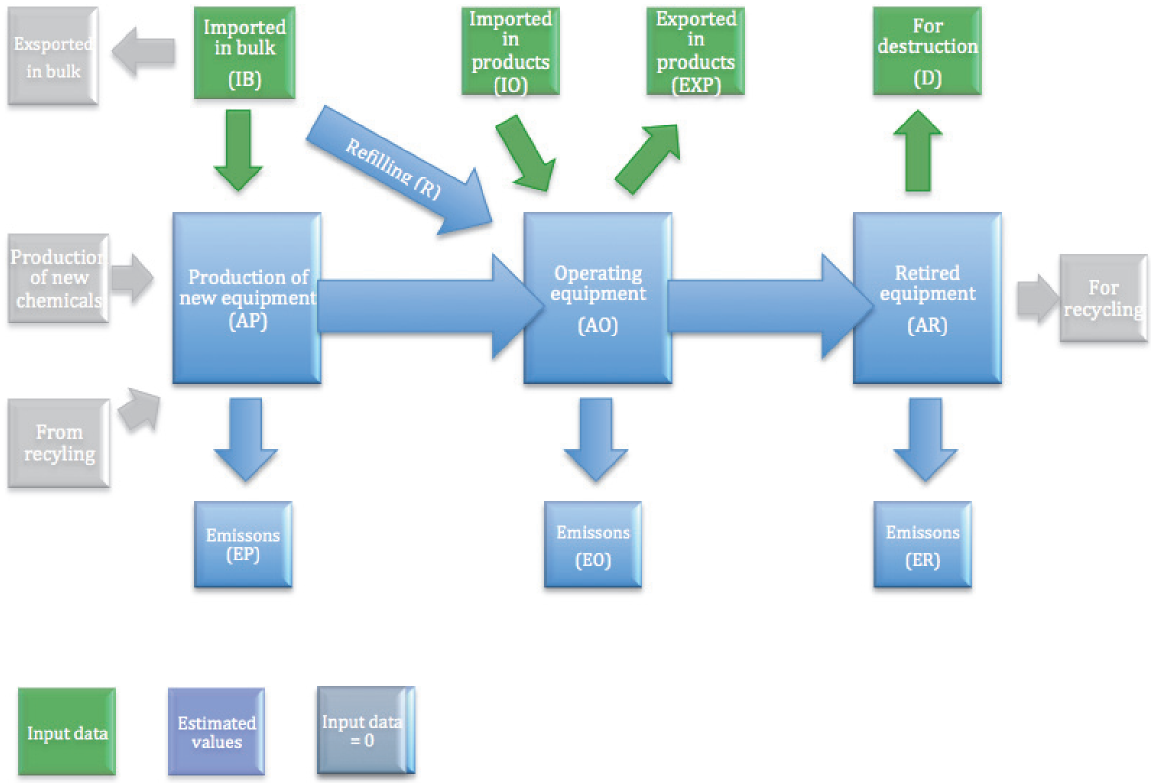
Application category (a)	Leakage rates for production of new equipment (EFP). Per cent of initial charge	Leakage rates for operating equipment (EFO). Per cent of initial charge/year	Lifetime (lt). Years
Refrigeration			
Domestic Refrigeration	Not occurring	0.5	15
Commercial Refrigeration			
Stand-alone Commercial Applications	Not occurring	3.5	10
Medium and Large Commercial Refrigeration	2	10	15
Transport Refrigeration	1	20	9
Industrial Refrigeration	2	10	15
Residential and Commercial A/C, including heat pumps	1	4	15
Mobile Air-Conditioning	Not occurring	Not applicable[2]	12
Foam			
Hard Foam	5	4.5	20
Soft Foam	Not occurring	Not occurring	Not occurring
Fire protection	2[1]	5	15
Aerosols			
Metered Dose Inhalers	Not occurring	50	2
Other aerosols	Not occurring	50	2
Solvents	Not occurring	50	2

[1]Country specific, see Haukås et al. (1999).
[2]A mass balance approach is used to estimate emissions from mobile air conditioning. See section 2.2.2.

Emissions are estimated separately for each of the applications categories listed in Table 2.1. Although calculations are made on a disaggregated level, due to the small number of companies involved in production of foams and fire extinguishers and in imports of aerosols in inhalators, emission figures for these application groups are published and reported in more aggregated groups.

According to the IPCC Guidelines, emissions should be calculated separately for the three general phases in the life cycle of a product: when the equipment is being produced (filled for the first time), when the product is in regular use (operating systems) and when the product is being retired (decommissioning). The reasoning behind this is that each phase gives rise to a particular emission pattern and should therefore have a proper emission factor allocated to it. Figure 2.1 illustrates the three phases of the life cycle of a product containing fluorinated substances and the flow of chemicals between the three phases.

Figure 2.1. The three phases in a product's life cycle and the flow of chemicals in and out of the phases



Hence, the total emission for each year (y), application category (a) and type of chemical (c) is as follows:

$$E_{y,a,c} = EP_{y,a,c} + EO_{y,a,c} + ER_{y,a,c}$$

$EP = Emissions\ from\ production\ of\ new\ equipment$
$EO = Emissions\ from\ operating\ equipment\ (equipment\ in\ use)$
$ER = Emissions\ from\ retired\ equipment$

The methodologies for estimating the net amount of chemicals in each phase and the emissions (blue boxes in Figure 2.1), are described in the following sections. The data sources for the activity data (green boxes in Figure 2.1) are described in chapter 3. The activity data in the grey boxes are not included in the calculations because they are not relevant or considered to be of little importance in Norway. There is no production of new chemicals or commercial recycling of HFCs and PFCs in Norway hence this is not considered as relevant activity data. Data on export of chemicals in bulk were collected by Klif up to 2009. These data show that exports of fluorinated substances are of insignificant importance to the Norwegian emission inventory. Exports of chemicals in bulk have therefore been set to zero for all years.

The application categories listed in Table 2.1 are divided into four groups (A-D) based on basic characteristics of their life cycle, see Table 2.2. The methodology differs slightly between the four groups, as described in the sections 2.1-2.3 below.

Product group A includes application categories which are assumed not to be produced in Norway. This means that all products in use have been imported to the country at some point. The applications in product group A are sealed units, which mean they are not being refilled at any point during use.

Product group B consists of only one application area: Foam. As opposed to product group A, foam products are being produced in Norway. Like group A there is no refilling at any point before decommissioning.

Product group C, mobile air conditioning, is similar to group A in that there is no domestic production of new equipment. Air conditioning equipment in cars and other mobile units are, however, normally refilled with chemicals several times before retirement.

Products in group D are both produced in Norway and they are being refilled with chemicals as long as they are in use. Note that some of these products are also imported.

As mentioned above, these characteristics imply that the methodology for estimating amounts of chemicals and the related emissions varies slightly between product groups.

Table 2.2. The four product groups and its characteristics[1]

Product group	Production of new equipment in Norway	Refilling of equipment in use	Application categories included in product group
A			Household refrigeration Small commercial refrigeration (plug-in units) Aerosols: inhalators Aerosols: other Solvents
B	x		Foam
C		x	Mobile air conditioning
D	x	x	Fire extinguishers Medium and large commercial refrigeration Transport refrigeration Industrial refrigeration Stationary air conditioning, including heat pumps

[1] Applications in all product groups may be imported.

2.1. Production of new equipment

When HFCs and PFCs are imported as chemicals in bulk to Norway, they can either be used for production of new equipment, or they can be used for refilling of equipment already in use. Medium and large refrigeration equipment for supermarkets are, for instance, typically built and filled on site. Foam blowing, where HFCs are used in the process of making construction materials, is another example of production of new “equipment” taking place in Norway.

2.1.1. Amounts of chemicals used for production of new equipment

Products in groups A and C are not produced in Norway. Hence the determination of the amount of chemicals used for production is only relevant for products in group B and D.

For group B products, i.e. foam blowing, the total amount of chemicals imported in bulk is used for production of new foam. The rationale for this is that there is no refilling of foam products.

For products in group D, the amount of chemicals imported can either be used for refilling of existing equipment, or for production of new equipment. We assume that products in this category are refilled in order to contain their original amount of chemicals every year. Hence we firstly determine the amount of chemicals needed for refilling of equipment, based on last year’s emissions from products in use. The amount of chemicals needed for refilling is initially put equal to the amount of chemicals having leaked out from last year’s bank (amount of chemicals in accumulated operating equipment), but it can never be higher than the bulk import. The difference between the amount of chemical imported in bulk and the amount used for refilling is assumed to be used for production of new equipment.

$$AP_{y,a,c} = IB_{y,a,c} \text{ for product group B}$$
$$AP_{y,a,c} = IB_{y,a,c} - EO_{y-1,a,c} \text{ for product group D}$$

$AP = Amount\ of\ chemical\ for\ production\ of\ new\ equipment$
$IB = Amount\ of\ chemical\ imported\ in\ bulk$
$EO = Emissions\ from\ operating\ equipment\ (equipment\ in\ use)$
$y = year$
$a = application$
$c = chemical$

The basic assumptions made are:
- ✓ No imports of chemicals to Norway prior to 1990
- ✓ No production of chemicals in Norway
- ✓ No recycling of chemicals from retired products
- ✓ No export of chemicals in bulk
- ✓ No production of group A and C products in Norway
- ✓ Products in group C and D are refilled to initial amount every year

2.1.2. Emissions from production of new equipment
The emissions for all production activities are calculated by applying emission factors to the amount of chemicals used for new production that year, see Table 2.1. The emission factors are within the range of factors recommended by the IPCC in its Guidelines from 1996 and 2006.

$$EP_{y,a,c} = AP_{y,a,c} \cdot EFP_a$$

$EP = Emissions\ from\ production\ of\ new\ equipment$
$AP = Amount\ of\ chemical\ for\ production\ of\ new\ equipment$
$EFP = Emission\ Factor\ (leakage\ rate) for\ production\ of\ new\ equipment$
$y = year$
$a = application$
$c = chemical$

2.2. Equipment in use - operating systems
This stage of the life cycle is relevant to all product groups and comprises the majority of the emissions. When products containing HFCs and PFCs are in use, the chemicals will gradually leak out through seams and holes in the equipment. Some products are sealed units with typically low leakage rates, and they are not refilled with new chemicals throughout their lifetime. Refrigerators and freezers used in households are examples of such equipment. As the chemicals leak out the equipment will gradually loose efficiency and eventually be decommissioned and replaced by new equipment. Larger equipment, for instance air conditioning equipment in office buildings or refrigeration systems in supermarkets, is refilled in order to keep up the efficiency throughout its operating lifetime. In all cases, as the chemicals are only gradually released, there will be a build up of "bank", i.e. the chemicals imported will accumulate in operating products and be emitted gradually depending on the leakage rate of the equipment.

2.2.1. Amount of chemicals in equipment in use
The bank (pool) of a chemical in a given year for a certain application group is estimated according to the statements below.

$$AO_{y(01.01),a,c} = AO_{y-1(31.12),a,c} - EO_{y-1,a,c}$$
$$AO_{y(31.12),a,c} = AO_{y(01.01),a,c} + (AP_{y,a,c} - EP_{y,a,c}) + IO_{y,a,c} + R_{y,a,c} - EXO_{y,a,c} - AR_{y,a,c}$$
$$R_{y,a,c} = EO_{y-1,a,c} \text{ for product groups C and D}$$
$$R_{y,a,c} = 0 \text{ for product groups A and B}$$

$AP = Amount\ of\ chemical\ for\ production\ of\ new\ equipment$
$AO = Amount\ of\ chemical\ in\ operating\ equipment$
$AR = Amount\ of\ chemical\ in\ redired\ equipment$
$EP = Emissions\ from\ production\ of\ new\ equipment$
$EO = Emissions\ from\ operating\ equipment\ (equipment\ in\ use)$
$IO = Amount\ of\ chemical\ imported\ in\ products$
$R = Amount\ of\ chemical\ for\ refilling\ of\ operating\ equipment$
$EXO = Amount\ of\ chemical\ exported\ in\ products$
$y = year$
$a = application$
$c = chemical$

This means that firstly, the amount of chemicals accumulated at the beginning of the year is established by subtracting last year's emissions from last year's bank (end of year). An important assumption is that the bank was zero prior to 1990. Then, the flow of chemicals in and out of the bank is added and subtracted. This means an addition of the amount of chemicals in newly produced products (the amount left after emissions in the production phase), amount in imported products and chemicals imported in bulk for refilling. Amounts of emitted chemicals and chemicals in exported products and products being retired and decommissioned are subtracted.

The amount needed for refilling of products is assumed to be zero for product groups A and B, and equal to last year's emission for product groups C and D. Calculation of amount of chemical in retired equipment is described in section 2.3.

2.2.2. Emissions from equipment in use

For all product groups, except group C, mobile air conditioning, the annual emissions are calculated using the emission factors shown in Table 2.1. It is important to note that the emission factors are applied to the original (initial) amount of chemical in a product, not the current bank size. This is done in accordance with recommendations by IPCC Guidelines. For group D products, which are assumed to be refilled and "topped up" every year, the resulting emissions will be equal for the two approaches. For groups A and B, which are not refilled and hence have an accumulated bank size that are lower than the products' initial amount, this approach will give higher emissions throughout the products' life span. It will accordingly have lower emissions during the waste phase.

For group C products, mobile air conditioning, a mass balance approach is used as a supplement to calculation with emission factor. Since there is no new production of mobile air conditioning equipment in Norway, all bulk chemicals imported are assumed to be used to refill after leakage. The emissions are hence assumed to be equal to or higher than imports of chemicals in bulk.

$$EO_{y,a,c} = EO_{y-1,a,c} + AON_{y,a,c} \cdot EFO_a - AON_{y-lt,a,c} \cdot EFO_a \text{ for product groups A og B}$$
$$EO_{y,a,c} = MAX(IB_{y,a,c}; AO_{y(31.12),a,c} \cdot EFO_a) \text{ for product group C}$$
$$EO_{y,a,c} = AO_{y(31.12),a,c} \cdot EFO_a \text{ for product group D}$$

$$AON_{y,a,c} = (IB_{y,a,c} - EP_{y,a,c} + IO_{y,a,c} + EXO_{y,a,c})$$

$EP = Emissions\ from\ production\ of\ new\ equipment$
$EO = Emissions\ from\ operating\ equipment\ (equipment\ in\ use)$
$EFO = Emission\ Factor\ (leakage\ rate) for\ operating\ equipment$
$AO = Amount\ of\ chemical\ in\ operating\ equipment$
$AON = Amount\ of\ chemicals\ in\ operating\ equipment\ which\ is\ new\ of\ the\ year$
$IB = Amount\ of\ chemical\ imported\ in\ bulk$
$IO = Amount\ of\ chemical\ imported\ in\ products$
$EXO = Amount\ of\ chemical\ exported\ in\ products$
$lt = life\ time\ (years)$
$y = year$
$a = application$
$c = chemical$

2.3. Retired equipment

As equipment gets old, it looses its functionality and gets decommissioned. If the equipment still contains chemicals, this can be collected for recycling or destruction. No recycling is assumed in Norway. If the chemicals in the decommissioned equipment are not collected in a proper way, they will slowly leak out or they can all be released at once.

2.3.1. Amounts of chemicals in retired equipment

The products are assumed on average to be in use a certain number of years before decommissioned. This average number of years is called the equipment’s lifetime and is given in Table 2.1.

For equipment which is refilled, i.e. product groups C and D, the amount of chemical contained in the product at the end of its lifetime is assumed to be the same as when the product was new. Hence the amount of chemical in retired equipment a certain year is equal to the amount of chemical in new products “lt” years before.

Equipment not being refilled will contain less chemical when decommissioned because of the annual leakage. See formulas below.

For some products, like inhalators, the whole content of HFC is emitted during the use of the product and the amount in retired product is zero.

$$AR_{y,a,c} = AON_{y-lt,a,c} \cdot (1 - lt \cdot EFO_a) \text{ for product groups A and B}$$
$$AR_{y,a,c} = AON_{y-lt,a,c} \text{ for product groups C and D}$$

$AR = Amount\ of\ chemical\ in\ redired\ equipment$
$AON = Amount\ of\ chemicals\ in\ operating\ equipment\ which\ is\ new\ of\ the\ year$
$EFO = Emission\ Factor\ (leakage\ rate) for\ operating\ equipment$
$lt = life\ time\ (years)$
$y = year$
$a = application$
$c = chemical$

2.3.2. Emissions from retired equipment

According to the methodology recommended by IPCC (1997), the total amount of chemical is emitted first year of decommissioning. Hence the emission factor is 1.

$$ER_{y,a,c} = AR_{y,a,c} - D_{y,a,c}$$

$ER = Emissions\ from\ retired\ equipment$
$AR = Amount\ of\ chemical\ in\ redired\ equipment$
$D = Amount\ of\ chemicals\ collected\ for\ destruction$
$y = year$
$a = application$
$c = chemical$

The amount of chemicals destructed is currently not exceeding the amount of chemicals in retired equipment. In case this should occur, the model is set up to subtract the extra amount from the amount of chemicals in equipment in use.

3. Data sources

As described in the previous chapter and illustrated in Figure 2.1, the input data to the model are amounts of chemicals flowing in and out of the country and amounts collected and destructed from retired equipment:

- ✓ Imports of chemicals in bulk (IB)
- ✓ Imports of chemicals in products (IO)
- ✓ Exports of chemicals in products (EXO)
- ✓ Destruction of chemicals (D)

These amounts are needed for each of the application (a) categories listed in Table 2.1 and for each of the relevant types of chemicals (c) listed in Table 1.1. The data are needed for each year, starting in 1990. It is assumed that there was no use of HFCs and PFCs before 1990.

The data sources described below provide in most cases data on chemical types, but will in general not provide information on the required level of detail for application categories. Assumptions are therefore made in order to distribute the chemicals to adequate application categories.

For 2010 and onwards, the emission estimates are based on annual updating of the required data. For the years 1990-2009, a time series has been constructed based on actual information for some years and an interpolation of data in the years between these data points. The data updated annually starting in 2010 are import data from the Norwegian Directorate of Customs and Excise (TAD) and destruction data from Stiftelsen Returgass (SRG). The time series 1990-2009 is a combination of data from a query performed in 1999 and data from the Norwegian Climate and Pollution Agency (Klif), in addition to data from TAD and SRG. More details are given below.

3.1. Data sources for emissions 2010 and onwards

This section gives a description of the data sources providing input data for estimating emissions for 2010 and onwards, using the methodology described in chapter 2. Note that the methodology is also used for calculating emissions for years prior to 2010.

3.1.1. The Norwegian Directorate of Customs and Excise

The Norwegian tax on imports of HFCs and PFCs is administrated by The Norwegian Directorate of Customs and Excise (TAD) through two declaration systems named “TVINN” and “AFS”. The information from the two data bases is combined in order to get figures on total imported amounts of chemicals. A detailed description of the information obtained from TVINN and AFS, and how this information is treated and combined, is provided in Hansen 2007. In brief, the TVINN register provides information about type of chemical and whether it is imported in bulk or in a product. When imported as bulk, the amount is allocated to an application category based on the name of the importer and type of chemical or blend of chemicals. When imported in a product, the amount is allocated to an application category based on its classification according to the Harmonised System (HS8). This is an international system for classification of goods developed by the World Customs Organization.

The AFS register does not contain information about the classification of imported products, hence the amount of chemical is allocated to an application category based on the name of the importer and type of chemical or blend of chemicals.

Information from TVINN is used by Statistics Norway in producing foreign trade statistics and is therefore readily accessible for use in the emission estimates. The following information is drawn from the data base once a year (for the year n-1):

- Year of import
- Tax rate
- Tax amount
- Product type (according to the international system for classification of goods “HS”)
- Importer (name and business register number)

Information from AFS is sent to Statistics Norway once a year (for the year n-1), specifically for the emission calculations:

- Year of import
- Tax rate group
- Tax amount
- Importer (name and business register number)

3.1.2. Stiftelsen Returgass

Stiftelsen Returgass (SRG) is the name of the company collecting and burning HFCs and PFCs in Norway. According to the industry, emissions from the destruction process are insignificant.

Collected amounts per type of chemical have been reported by SRG to Klif once a year (n-1) since 2004, and are also provided to Statistics Norway. No information about the application categories from which the chemicals are collected, is available. Since the amounts are small and hence of minor importance to the emission inventory, the origin of the chemicals are not tracked, but allocated to application categories by Statistics Norway according to assumptions about common use for each type of chemical

3.2. Data sources for emissions 1990-2009

This section gives a short description of the data sources providing input data for emission estimates for the years 1990-2009.

3.2.1. The Norwegian Climate and Pollution Agency

Up until 2009, Klif collected annual reports from companies importing or exporting HFCs and PFCs in **bulk**. The companies reported the amount imported/exported by type of chemical and use category: refrigeration, foam blowing, fire extinguishers, aerosols or laboratory analysis.

In order to obtain adequate input data for the emission estimates, the bulk data collected by Klif had to be allocated to each of the relevant application categories listed in Table 2.1. This was done by using data from TAD for the years 2005-2006 to get information about the relative importance of each application category.

For imports of HFCs and PFCs in bulk for use in production or refilling of stationary and mobile air conditioning, the data from Klif were not used. Amounts of chemicals were compiled from the TAD registers for the years 2005-2006 and 2010, and a linear interpolation was applied for the years prior to and after, assuming no imports in 1990.

3.2.2. Query by Statistics Norway and the Norwegian Climate and Pollution Agency

Haukås et al. (1999) gives a description of the query performed by Statistics Norway and the Norwegian Climate and Pollution Agency for the years 1995-1997. The query collected data on consumption and use of HFCs and PFCs in **products** from major importers and exporters in Norway. Data from this query were used in combination with data from TAD for the years 2003-2004 and 2010, as described in Hansen (2007). Assuming imports started in 1990, the data were given a linear growth/decrease in the years between these data points (i.e. 1991-1994, 1998-2002, 2005-2009).

3.2.3. Stiftelsen Returgass

Data on destructed amounts of HFCs and PFCs were provided by Stiftelsen Returgass, the company collecting and burning fluorinated substances in Norway. See description in section 3.1.2.

4. Results

The calculations made as described in previous sections, show that Norwegian emissions of fluorinated substitutes for ozone depleting substances amounted to a total of 950 000 tonnes of CO_2-equivalents in 2011. This is 1.8 per cent of the total Norwegian emissions of greenhouse gases and about the same "per capita"-level as other European countries.

The emissions are assumed to have been close to zero before 1990, and have gradually increased as they are replacing the ozone depleting substances that are being phased out under the Montreal protocol. As in most other industrialized countries, emissions of fluorinated gases in Norway are still small compared to other emission sources, but of increasing importance.

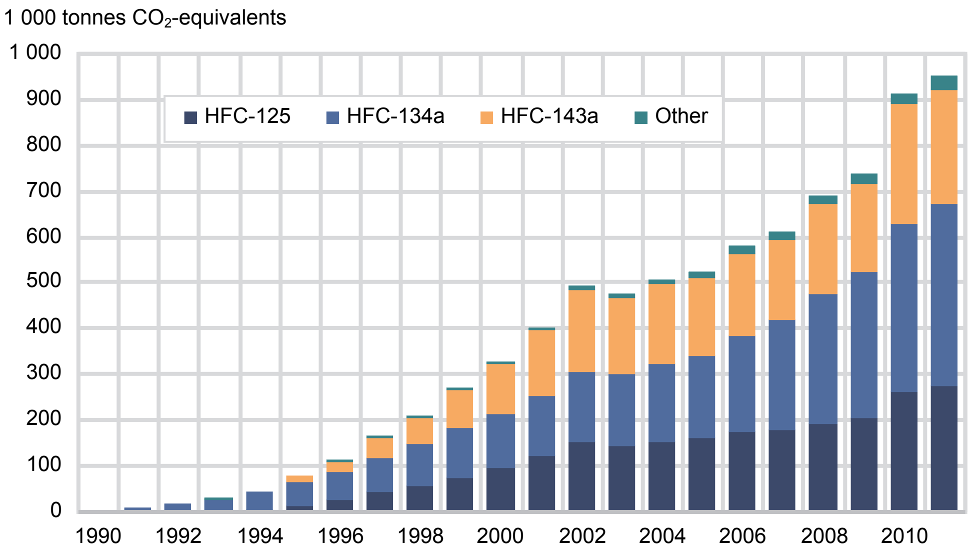
Table 4.1 and Figure 4.1 show the development in emissions from 1990-2011. More detailed tables are provided on the UNFCCC web pages (unfccc.int), under National Reports and GHG data.

Although emissions of several types of fluorinated substances occur, there are three chemicals dominating the emissions: HFC-134a, HFC-125 and HFC-143a. They are all widely used for refrigeration and air conditioning.

Table 4.1. Emissions of HFCs and PFCs from product use. 1 000 tonnes CO_2-equivalents

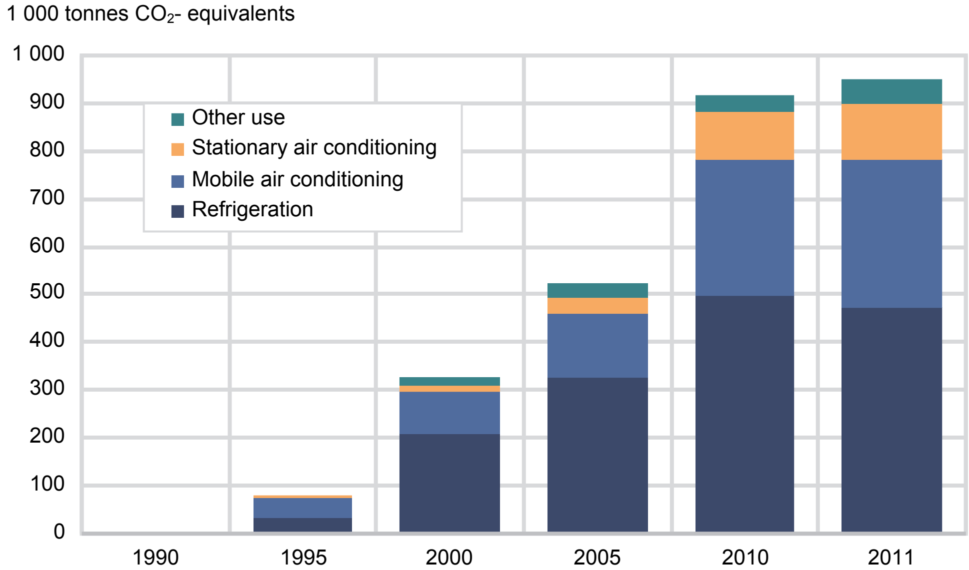
	1990	1995	2000	2005	2010	2011
HFC-23	-	0.1	0.7	1.7	1.3	1.9
HFC-32	-	0.3	1.3	3.9	12.8	14.5
HFC-125	<0.1	14.5	97.4	159.6	263.5	276.7
HFC-134	-	-	-	0.8	1.9	1.8
HFC-134a	<0.1	49.9	117.3	180.9	364.0	397.4
HFC-143	-	-	-	0.3	0.3	0.3
HFC-143a	<0.1	15.4	109.0	169.5	263.0	245.8
HFC-152a	<0.1	0.2	1.1	4.3	5.5	5.6
HFC-227ea	-	-	0.5	2.9	2.0	6.1
PFC-218	-	0.2	0.2	0.1	-	-
Total	**<0.1**	**80.6**	**327.6**	**524.2**	**914.4**	**950.2**

Figure 4.1. Emissions of HFCs and PFCs from product use in Norway. 1 000 tonnes CO_2-equivalents



A tax on imports of HFCs and PFCs to Norway was introduced in January 2003. The high estimate for emissions in 2002 is probably caused by the tax, as the imports of these chemicals were higher than normal that year. It is likely that the real emissions due to this import peak were more evenly distributed over the subsequent years. The jump in estimated emissions from 2009 to 2010 may be due to the introduction of a new data source (see section on areas of further improvement).

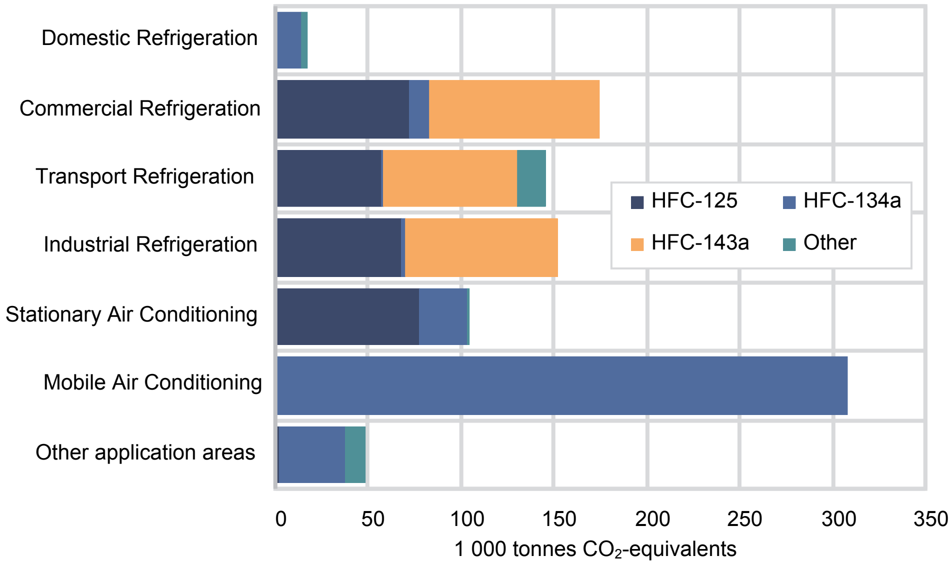
Figure 4.2. Development in emissions from refrigeration, mobile and stationary air conditioning, and other sources. 1990- 2011. 1 000 tonnes CO_2-equivalents



About one third of the emissions came from mobile air conditioning in 2011. See Figure 4.2 and Figure 4.3. Two factors have been pushing these emissions upwards: an increasing share of cars having air conditioning equipment, and an increase in number of vehicles. Both factors are largely due to economic growth. While air conditioning in cars was not very common in Norway 20 years ago, almost all new cars have this kind of equipment today. Currently, HFC-134a is the chemical used as refrigerant in the air conditioning equipment. Companies are however testing alternatives with lower GWP-values. These alternatives can not be applied to existing air conditioning equipment without modifications of the systems, hence on short term emissions from cars are expected to grow. On longer term, however, replacement of HFC-134a with other refrigerants may lead to a decrease in future emissions from this source, even though the car park is expected to continue to increase.

Stationary air conditioning is also a growing emission source in Norway. It accounted for about 12 per cent of the emissions of HFCs and PFCs in 2011. Stationary air conditioning includes equipment of various sizes, from small heat pumps used in private homes to large installations in for instance office buildings or hospitals. The sale of heat pumps for private homes has grown steadily during the last decade. According to Statistics Norway's energy statistics approximately 4 per cent of the households owned a heat pump in 2004. This share had grown to about 19 per cent in 2009. The increasing popularity of heat pumps is probably due to higher energy prices. Heat pumps are normally filled with blends containing HFC-32, HFC-125 and HFC-134a. Alternatives are also available, but most commonly used in the larger installations.

Figure 4.3. Emissions by source category and type of chemical in 2011. 1 000 tonnes CO_2-equivalents



According to this study, almost 70 per cent of the fluorinated substances accumulated in products in Norway in 2011 were stored in mobile and stationary air conditioning equipment, which is a considerably higher share than in the concurrent emissions. Less than 20 per cent were stored in refrigeration equipment, such as domestic, commercial, industrial and transport refrigeration. This indicates that a higher share of emissions will come from air conditioning equipment in the future. A decade earlier, the amount of chemicals stored in refrigeration equipment and air conditioning equipment comprised about 40 per cent of the accumulated chemicals each. This shift is a consequence of opposing trends in the two application areas. Whereas the use of HFCs for air conditioning is still increasing, the consumption of HFCs for refrigeration seems to have stabilized and have even decreased the last few years. This is opposed to the fact that economic growth and increasing consumption of goods in Norway implies that the need for refrigerants should still be increasing. This might indicate that the taxation of fluorinated substances have had the intended effect of reducing imports of these chemicals. According to the industry, the larger scale application areas are now increasingly using alternative technology employing less or no HFC.

The use of HFCs for other application areas is also by large decreasing. The category “Other use” in Figure 4.2 consists of emissions from foam products, like insulation mats and other construction materials, fire extinguishers, canisters where HFCs are used as propellants (aerosols) and for cleaning (solvents). This group only contributes to 5 per cent of the emissions.

This study also indicates that there is still a big potential in collection and destruction of fluorinated substances. Comparing the estimated amount of chemicals in retired products for the whole period 1990-2011 with the total amount of chemicals collected for destruction since 2004, indicates that only one sixth of the chemicals in retired products have been collected for destruction. This estimate is, however, highly uncertain due to the many assumptions in the calculations concerning lifetime and refilling.

4.1. Recalculations - consequences

The first chapter of this document provides the reasoning behind the changes made to the calculations of emissions of HFCs and PFCs from product use in Norway (section 1.1).

As a consequence of updating emission factors (including lifetimes), activity data and the application of a new calculation model, the emissions increased by 168 000 tonnes CO_2 equivalents (up 22 per cent) in 2010, to 915 000 tonnes CO_2 equivalents. Table 4.2 gives an overview of the changes in emissions for all years, both in tonnes and per cent. The table shows that HFC-134a, HFC-125 and HFC-143a are the chemicals primarily affected.

According to the new calculations, the total emissions have been underestimated for all years in the previous calculations. This is mainly due to changes made in the calculation methodology and emission factors (i.e.

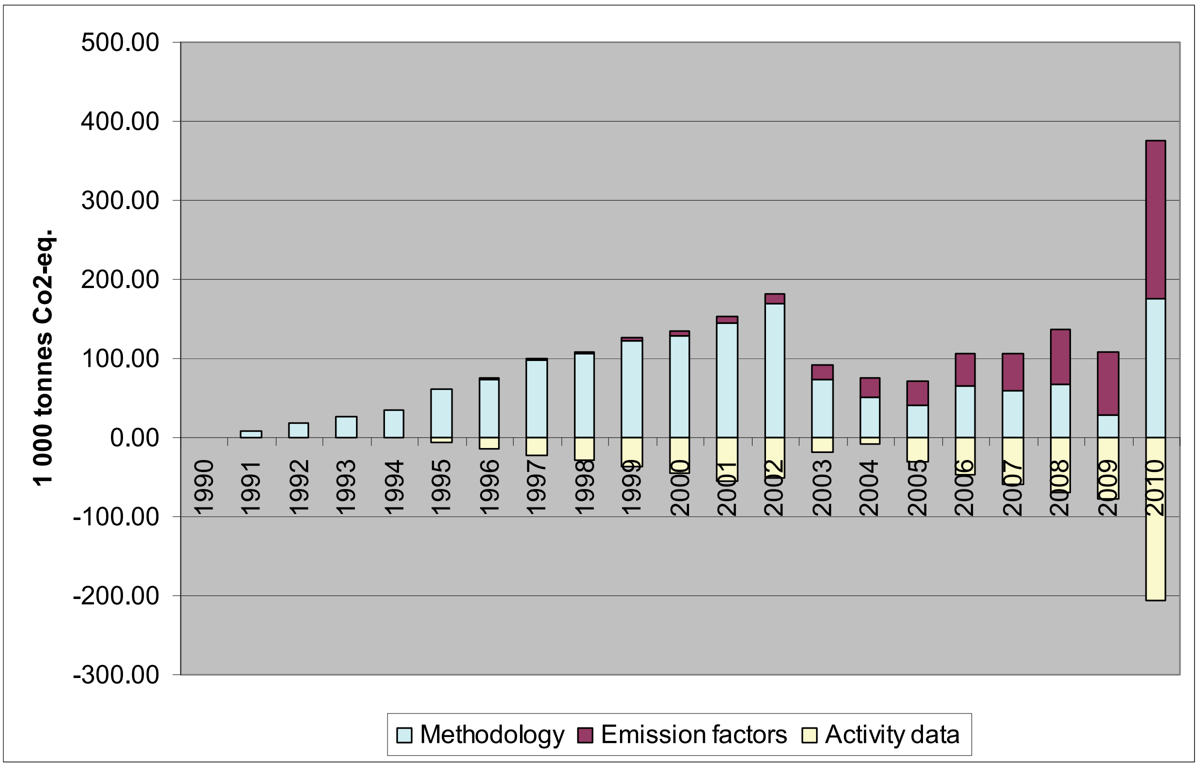
reduced lifetime for some products) resulting in emissions occurring earlier in time. New activity data have pulled in the opposite direction, as the imports of chemicals in general are lower in the current estimate.

Table 4.2. Difference in emissions before and after recalculations (current minus previous estimate)

	Total		HFC-23	HFC-32	HFC-125	HFC-134	HFC-134a	HFC-143	HFC-143a	HFC-152a	HFC-227ea	PFC-218
	1 000 tonnes CO_2-eq	Per cent	Tonnes									
1990	**0.05**	**173**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00
1991	**9.01**	**7 841**	0.00	0.03	0.04	0.00	6.72	0.00	0.00	0.21	0.00	0.00
1992	**18.12**	**5 303**	0.00	0.10	0.10	0.00	13.39	0.00	0.00	0.19	0.00	0.00
1993	**26.45**	**1 322**	0.00	0.18	0.19	0.00	19.51	0.00	0.00	0.03	0.00	0.00
1994	**35.19**	**391**	0.00	0.29	0.96	0.00	23.44	0.00	0.43	0.04	0.00	0.00
1995	**54.35**	**209**	0.00	0.42	2.82	0.00	28.18	0.00	2.54	0.29	0.00	0.03
1996	**60.24**	**116**	0.01	0.57	3.54	0.00	29.54	0.00	2.91	-0.03	0.06	0.05
1997	**77.86**	**89**	0.03	0.62	5.80	0.00	32.75	0.00	4.85	1.02	0.05	0.04
1998	**79.86**	**61**	0.00	0.74	5.81	0.00	34.40	0.00	4.88	0.51	0.01	0.04
1999	**89.89**	**50**	0.00	0.83	7.20	0.00	31.97	0.00	7.48	-2.10	0.00	0.03
2000	**89.45**	**38**	0.00	0.96	8.64	0.00	25.93	0.00	8.21	-4.17	0.00	0.03
2001	**99.21**	**33**	0.00	1.11	10.68	0.00	20.82	0.00	11.11	-5.79	0.15	0.03
2002	**128.94**	**36**	0.00	1.08	15.60	0.00	20.75	0.00	14.86	-8.69	0.92	0.02
2003	**72.31**	**18**	-0.03	1.16	9.21	0.00	10.38	0.00	8.89	-12.06	0.23	0.02
2004	**68.73**	**16**	-0.05	1.22	9.75	1.03	1.17	0.00	10.09	-3.95	0.15	0.02
2005	**42.23**	**9**	0.03	1.50	9.20	0.75	-9.86	0.70	7.27	-1.12	-0.09	0.01
2006	**59.64**	**11**	0.00	2.53	12.97	0.67	-9.93	0.65	9.22	-4.58	-0.32	0.00
2007	**47.29**	**8**	-0.02	3.54	11.55	0.59	-8.49	-0.14	6.22	0.85	-0.13	0.00
2008	**68.13**	**11**	-0.05	4.79	13.60	2.66	-8.51	-0.29	9.94	-3.12	-0.44	0.00
2009	**28.65**	**4**	-0.06	7.22	16.59	2.07	-36.49	-0.45	6.77	-4.14	-0.40	-0.01
2010	**167.62**	**22**	-0.04	10.33	34.07	1.85	-20.30	-0.60	24.67	-3.31	-0.76	-0.01

Figure 4.4 shows the influence on total emissions for each year, by the changes made in methodology (blue bars), emission factors (red bars) and activity data (yellow bars). The figure illustrates that in the beginning of the time series, changes in methodology was responsible for almost 100 per cent of the emission changes in the recalculations. Towards the end of the time series, the three groups of changes are equally important – each causing a change in emissions of about 1/3 of the total change. This means that if only activity data was updated in 2010, the emissions would have been about 207 000 tonnes CO_2 equivalents lower than the previous estimates. If only emission factors were updated, the emissions would have been about 199 000 tonnes CO_2 equivalents higher than the previous estimates. And finally, if only the methodology had been changed, the emissions would have been about 176 000 tonnes CO_2 equivalents higher than the previous estimates. The net increase in the emissions after performing all three changes was therefore 168 000 tonnes CO_2 equivalents.

Figure 4.4. The influence of change in methodology (blue bars), emission factors (red bars) and activity data (yellow bars) on the recalculations/emission estimates



Methodological changes
Accumulated over time, it is the change in methodology that is responsible for the largest share of changes in the recalculation of emissions. An important methodological change is that the *new* model bases the emission estimates on the original amount of chemical filled in to a product. The emission factors are applied to the amount of chemical that a product initially contained, even if some of the chemical has leaked out over time. This is in line with the recommendations of IPCC (1997). The old model applied the emission factors to the amount stored in the products at any given time. For products not being refilled, like household refrigeration and foam products, this “new” methodology will cause the chemicals to be released at a higher pace. It is important to note that this will not lead to a change in the total amount of chemicals emitted over time, but it makes the emissions occurring earlier in time.

For one product group, i.e. mobile air conditioning, the emissions are now based on a mass balance approach, i.e. the emissions are equal to imports of chemicals for refilling, as long as the import exceeds the emissions estimated from emission factor and the amount stored in products. This has also caused the emissions to increase.

Of less importance is the fact that the new model takes amounts of destructed chemicals into account. This has slightly lowered the emissions.

Changes in emission factors, including lifetime
The changes in emission factors have also contributed to higher emissions, but this has mainly had an effect on later years. A reduction in lifetime for some products has lead emissions to occur earlier in time than what was estimated in the previous model. For some products the emission factors are higher, for some they are lower. These changes will have opposed effects on the emissions. See Table 4.3 with new and old emission factors and lifetimes. The effects are accounted for in the red bars in figure 4.4.

Table 4.3. Emission factors used before and after recalculations. Old values shown in bold

Application category	Leakage rates for production of new equipment. Per cent of initial charge		Leakage rates for operating equipment. Per cent of initial charge/year		Lifetime (years)	
	New	Old	New	Old	New	Old
Refrigeration						
Domestic Refrigeration	Not occurring		0.5	1	15	
Commercial Refrigeration						
Stand-alone Commercial Applications	Not occurring		3.5		10	15
Medium and Large Commercial Refrigeration	2		10		15	
Transport Refrigeration	1	2	20		9	15
Industrial Refrigeration	2		10		15	
Residential and Commercial A/C, including heat pumps	1	2	4		15	
Mobile Air-Conditioning	Not occurring		Not applicable[2]	10	12	
Foam	5		4.5	1 and 3	20	30/40
Fire protection	2[1]		5		15	
Aerosols						
Metered Dose Inhalers	Not occurring		50		2	
Other aerosols	Not occurring		50		2	
Solvents	Not occurring		50		2	

[1]Country specific, see Haukås et al. (1999)
[2]A mass balance approach is used to estimate emissions from mobile air conditioning. See section 2.2.2.

Activity data

The yellow bars in figure 4.4 show the effect of updating the activity data (see chapter 3 for a description of activity data). The updating has overall lead to a decrease in emission figures. The estimated net consumption decreased because of lower total imports for the whole period 1990-2010 for HFC-134a and HFC-152a, and less importantly for HFC-143a and HFC-125. Estimated net consumption increased for the other chemicals. As projections based on data collected in mid 90ties were replaced by import statistics, the current activity data are believed to be of much higher quality. Projections seem to have been overestimating imports of chemicals, particularly in hard foam products, and underestimating imports in stationary air conditioning.

5. Areas of further improvement

This section lists some of the areas in the calculation process and emission estimates that would benefit from further work and development.

Further extraction of data from the Norwegian Directorate of Customs and Excise could improve the quality of the input data to the model in several ways:

- Currently, the data from TVINN only contains indirect information about which gas is being imported, i.e. tax rate. For most substances, the tax rate is unique. For substances without a unique tax rate, the imported amounts may be incorrectly matched with type of chemical. This is currently only a problem for HFC-134a and HFC-43-10. As tax rates are not constant, this problem might increase in the future.
- Along with the switch from using Klif as primary data source for imports of chemicals in bulk in 2009, to using TAD as primary data source in 2010, there was a jump in the emissions. A comparison of data from the two data sources for 2009 could reveal whether the jump in emissions is due to changes in activity or due to change of data source.
- Exports of chemicals are assumed to be small and of little importance to the emission estimates. It could be useful to look further into this issue and provide better documentation for this assumption.

Adjustments and/or verifications of the emission factors used in the calculations could be obtained after analyzing and comparing estimated emissions with imported amounts of chemicals for refilling. This kind of analysis should be performed for equipment like refrigeration and air conditioning. Non-commercial recycling of chemicals within companies could complicate this kind of analysis because information about this activity is not readily available.

The calculation process, i.e. the process from collection of input data to dissemination of statistics and reporting, has been changed in order to save time and resources. There is however still potential resources to be saved in further streamlining and automation of the process, for example in applying more automatic controls of input data and results.

References

Hansen, K.L. (2007): *Emissions from consumption of HFCs, PFCs and SF_6 in Norway*, Documents 2007/8, Statistics Norway http://www.ssb.no/english/subjects/01/04/10/doc_200708_en/doc_200708_en.pdf

Haukås et al. (1999). Hans T. Haukås, Sigurd Holtskog (SN) and Marit V. Pettersen (SFT). "Calculations of emissions of HFCs and PFCs in Norway". Norwegian Pollution Control Authority. Report 99:03

IPCC (1997): *Greenhouse gas inventory. Revised 1996. IPCC guidelines for national greenhouse gas inventories*, London: Intergovernmental panel on climate change

IPCC (2006): *2006 IPCC guidelines for national greenhouse gas inventories*, Institute for Global Environmental Strategies (IGES)

List of figures

List of tables

B Retun to:
Statistisk sentralbyrå
NO-2225 Kongsvinger

Statistics Norway 24/2013 Emissions of HFCs and PFCs from product use in Norway

From:
Statistics Norway

Postal address:
PO Box 8131 Dept
NO-0033 Oslo

Office address:
Kongens gate 6, Oslo
Oterveien 23, Kongsvinger

E-mail: ssb@ssb.no
Internet: www.ssb.no
Telephone: + 47 62 88 50 00

ISBN 978-82-537-8685-8 (printed)
ISBN 978-82-537-8686-5 (electronic)
ISSN 1891-5906

ISBN 978-82-537-8685-8
9 788253 786858

Design: Siri Boquist

Statistisk sentralbyrå
Statistics Norway