Update of the national emission inventory (1990 – 2021) and projections (2021 – 2050) of ozone depleting substances and fluorinated greenhouse gases

PART A: Emission inventory 1990 – 2021

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Vision on technology for a better world

ECONOTEC CONSULTANTS

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PART A: Emission inventory 1990 – 2021

Public report

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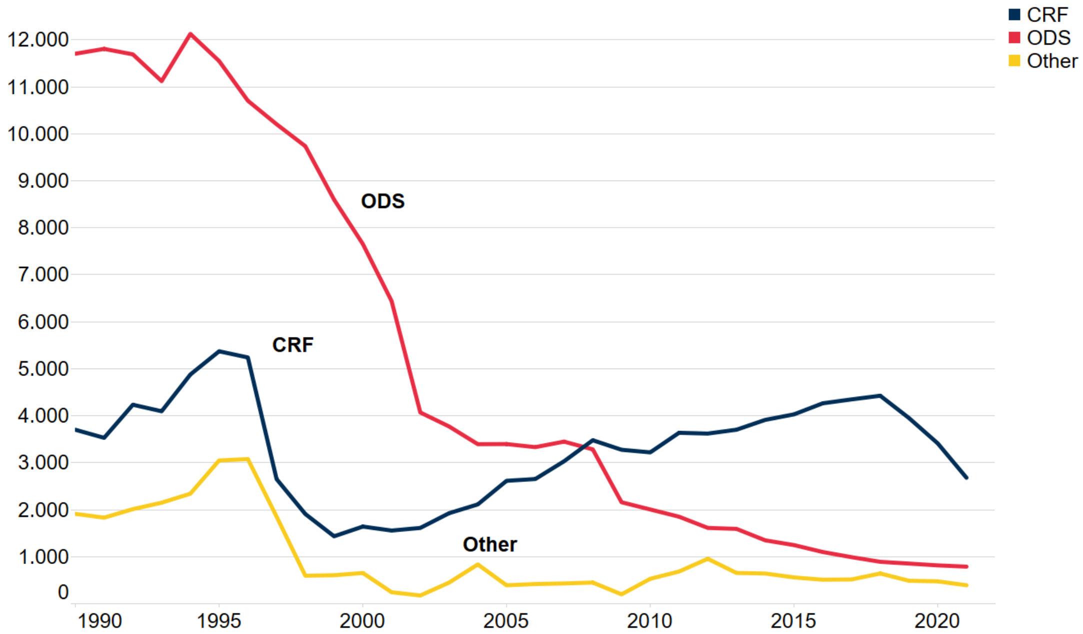
SUMMARY

In the present study the Belgian emission inventory of ozone depleting substances and fluorinated greenhouse gases covered by both the Montreal Protocol and the Kyoto protocol were estimated and updated for the years 1990-2021.

For each year, the emissions have been evaluated by region, by emission source, by type of emission (manufacturing emissions, operating losses, disposal emissions) and by individual substance. In total, emissions from 10 CRF categories (2.B.9., 2.E.1, 2.E.4., 2.F.1., 2.F.2., 2.F.3., 2.F.4., 2.F.5., 2.G.1., and 2.G.2.) have been quantified for 30 greenhouse gases.

The emissions of the four fluorinated greenhouse gases under the Kyoto protocol (HFCs, PFCs, SF6 and NF3), expressed in kt CO_2-eq, are shown on Figure 0-1 by gas and on Table 0-1 by category.

Figure 0-1. Emissions of CRF F-gases by gas category in Belgium (in kt CO_2-eq).



Source: VITO, Econotec (own calculations, 2022).

Table 0-1. Evolution of the CRF F-gas emissions by source (in kt CO_2-eq).

		2005	2010	2015	2020	2021
2.B.9.	Fluorochemical production	769	587	1077	840	275
2.E.1.	Integrated circuit or semiconductor	16	12	13	52	42
2.E.4.	Heat transfer fluids	0	0	0	0	0
2.F.1.a	Commercial refrigeration	1.183	1.669	1.847	1.437	1.293
2.F.1.b	Domestic refrigeration	1	2	2	1	1
2.F.1.d	Transport refrigeration	26	41	36	22	18
2.F.1.e	Mobile air-conditioning	220	369	419	342	305
2.F.1.f	Stationary air-conditioning	97	228	378	534	566
2.F.2.a	Closed cell foam	116	119	69	44	46
2.F.3.	Fire protection	13	14	14	11	10
2.F.4.a	Metered dose inhalers	36	42	45	44	44
2.F.4.b	Other aerosols (technical aerosols)	46	32	38	1	1
2.G.1.	Electrical equipment	12	16	11	11	8
2.G.2.c	Soundproof windows	72	89	81	74	71
2.G.2.d	Adiabatic properties: shoes and tyres	8	0	0	0	0
2.G.2.e	SF6 and PFCs from other product use	0	0	0	0	0
Total		**2.615**	**3.220**	**4.029**	**3.412**	**2.680**

Source: VITO, Econotec (own calculations, 2022).

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LIST OF ABBREVIATIONS

AR4	Fourth Assessment Report of the IPCC
AR5	Fifth Assessment Report of the IPCC
CFC	Chlorofluorocarbon
CRF	Common Reporting Format of the UNFCCC
CRF F-gas	compulsory gas for the UNFCCC reporting
FGR	F-gas regulation
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
HFE	Hydrofluoroether
HFO	Hydrofluoroolefin
IPCC	Intergovernmental Panel on Climate Change
MDI	Metered Dose Inhaler
NF3	Nitrogen trifluoride
NIR	National Inventory Report for UNFCCC
ODS	Ozone-depleting substance
ORC	Organic Rankine Cycle
PFC	Perfluorocarbon
PFPMIE	Perfluoropolymethylisopropyl ether
PU	Polyurethane
XPS	Extruded Polystyrene
UNFCCC	United Nations Framework Convention on Climate Change

1 INTRODUCTION

The present study updated for the years 1990-2021 the Belgian emission inventory of ozone depleting substances and fluorinated greenhouse gases. The emissions have been quantified by region[1], by emission source, by type of emission (manufacturing emissions, operating losses, disposal emissions) and by individual substance.

This report describes the methodology to assess emissions for each category, the improvements and updates that were made, the results and the outcome of the uncertainty analysis.

The inventory has been established according to the latest UNFCCC guidelines, which are applicable since the 2015 submission of the national inventory (Decision 24/CP.19). These guidelines implement the 2006 IPCC Guidelines [1].

In May 2019, the IPCC approved the “2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories” [2]. It will not replace the 2006 IPCC Guidelines. It is meant to be used in conjunction with the 2006 IPCC Guidelines. For most sectors, such as solvents, aerosol and fire protection, there is no refinement proposed. Where it is relevant, the refinement has been considered.

International trade in fluorinated greenhouse gases

Results international trade

Statistics on international trade in fluorinated greenhouse gases, gathered from Eurostat, are presented in Annex D. Since 2016, Eurostat data have become available for the main individual HFCs or HFC mixtures. These statistics are only given for information. They have not directly been used for setting up the emission inventory, because of their limitations (see Annex D).

Illegal trade

The entry into force of the HFC phasedown of EU regulation 517/2014 has given rise to illegal HFC import in Europe [3]. According to an analysis by the EU Commission [4], imports of HFCs declared at customs seem to be correctly reported under the F-gas regulation (FGR), and therefore most illegal trade appears to be in the form of an evasion of customs (cross-border smuggling). Up to now it does not appear possible to quantify this customs evasion, even at EU level. However, it has been estimated that the amount of illegal imports could be as high as 34 million tonnes CO_2-eq, or 33% of the legal EU HFC market (https://stopillegalcooling.eu). The main amounts of illegal HFCs were seized in eastern European countries (Rumania, Bulgaria, Poland, Greece, as well as in Spain, Italy and the Netherlands (https://stopillegalcooling.eu), but non-refillable containers (prohibited by the FGR and a possible sign of illegal trade) have also been observed in Belgium.

It is therefore likely that HFC supply data obtained through our data collection and used for the emission inventory underestimate the actual supply. Unfortunately, we do not know to what extent. As the impact of this oversupply on the current emissions is

[1] Unless otherwise mentioned all tables and figures are given for Belgium as a whole.

probably limited for the time being (for the quantities concerned are mostly stored in equipment), we have decided to neglect it. In the meantime, action against illegal trade is being undertaken by the EU Commission, Member States and EFCTC [5], notably by encouraging the report of illicit F-gas products and imports. Should better information on the amount of illegal trade become available in the future, it could be used to adapt the inventory.

Included sectors

Table 1-1. CRF categories included in this report.

	Sector
2.B.	Chemical industry
2.B.9.	Fluorochemical production
2.E.	Electronics industry
2.E.1.	Integrated Circuit or Semiconductor
2.E.4.	Heat Transfer Fluid
2.F.	Product uses as substitutes for ODS
2.F.1.	Refrigeration and Air-conditioning Equipment
2.F.1.a.	Commercial refrigeration
2.F.1.b.	Household refrigeration
2.F.1.c.	Industrial refrigeration
2.F.1.d.	Transport refrigeration
2.F.1.e.	Mobile air-conditioning systems
2.F.1.f.	Stationary air-conditioning systems
2.F.2.	Foam Blowing Agents
2.F.3.	Fire Extinguishers
2.F.4.	Aerosols
2.F.4.a.	Metered-dose inhalers
2.F.4.b.	Other aerosols
2.F.5.	Solvents
2.G.	Other product manufacture and use
2.G.1.	Electrical Equipment
2.G.2.	SF6 and PFCs from Other Product Use
2.G.2.b.	Particle accelerators
2.G.2.c.	Soundproof windows
2.G.2.d.	Adiabatic properties: shoes
2.G.2.e.	SF6 and PFCs from other product use

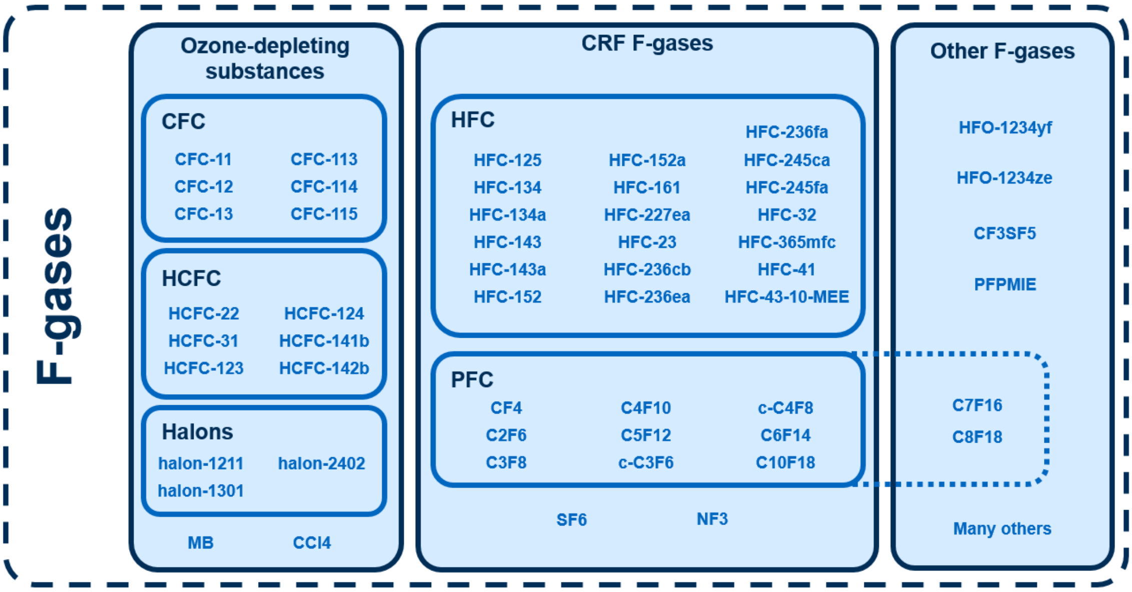
Included gases

The updated inventory takes into account 71 gases:

- the 30 compulsory gases of the UNFCCC and EU reporting (19 HFCs, 9 PFCs, SF6 and NF3), 21 gases with non-zero emission values;
- 18 ODS gases, 12 gases with non-zero emission values;
- 2 other PFCs (C7F16, C8F18), PFPMIE, CF3SF5, C8F16O, 1 HCFO and 3 HFOs.
- as well as the other substances emitted by the chemical industry. Out of these substances, 29 have non-zero emission values.

The substances can be grouped by type (i.e. CFCs, HCFCs, Halons, HFCs, PFCs, SF6, NF3, HFOs and Other) or further aggregated into three main groups defined by the legislation that regulates emissions: ODS (ozone depleting substances, covered under the Montreal Protocol), CRF (substances for which there is a reporting obligation in the CRF format, covered under EU and international climate legislation), and Other.

Figure 1-1. Overview of included substances, type of gases (CFC, HCFC, halons, HFC PFC), and categories (Ozone-depleting substances, CRF F-gases, other F-gases).



Note: C7F16 and C8F18 are both PFCs that are not covered by UNFCCC or EU legislation and therefore are no CRF F-gases.

Global Warming Potential values (GWP)

In accordance with Decision 18/CMA.1 and the EU Delegated Regulation 2020/1044 the GWP values used for the CRF F-gases are those listed in Annex I and the Fifth Assessment Report of the IPCC. For the remaining substances, the best available data have been used, among which those of the Sixth Assessment Report of the IPCC.

See Annex B for an overview of the used GWP values.

Box 1. Units and conversions

Emissions of fluorinated greenhouse gases presented in this report are normally given in either tonnes (t) or kilotonnes CO_2-equivalent (kt CO_2-eq).
Conversion of tonnes of greenhouse gas emitted into tonnes CO_2-equivalent:

tonnes of GHG * GWP / 1000 = kilotonnes of GHG in CO_2-equivalent.

The GWP is the Global Warming Potential of the greenhouse gas. The GWPs of fluorinated greenhouse gases used in this report are given in Annex B.
Conversion of tonnes of ozone-depleting substance emitted into tonnes CFC-11-equivalent:

tonnes of ODS * ODP = tonnes of ODS in CFC-11-equivalent

The ODP is the Ozone Depleting Potential of the ODS. The ODPs of gases used in this report are given in Annex B.

Regionalisation of emissions

Depending on the emission source, the national emissions are divided among the three regions using one of two alternative approaches:

- When the emissions are estimated at the level of sources located in individual regions, they are attributed to these regions. This is the case of the manufacturing emissions of 'chemical industry', 'Car airco', 'Trucks airco', 'Foams', 'Aerosols', 'SF6 in glass sector', 'Chemical industry') and of the process emissions of 'Methyl bromide'.
- The remaining emissions are regionalised using one of several (yearly) distribution keys: population, electricity consumption, and number of private cars.

Tasks

The inventory has been set up in a manner consistent with those of the previous years, according to the methodology first developed by ECONOTEC in 1999 [6] and later improved and enhanced in collaboration with VITO in the course of the annual updates.

The same methodology was applied for all years from 1995 to 2021. Where improvements have been made to the methodology or to emission factors, or a new source has been added, recalculations have been made.

The following tasks have been or will be carried out:

1. Data collection, among which:
    - enquiry among the refrigerant suppliers
    - enquiry among manufacturers of products containing fluorinated greenhouse gases (automobiles, air-conditioning appliances, air dryers, foam, technical aerosols…)
    - enquiry among the fire extinction contractors and the semiconductor industry
    - collection of data on recovery and destruction of fluorinated greenhouse gases from the individual companies

- collection of statistical data (cars, buses & coaches, external trade, registration of new refrigerated trucks and trailers, population…)
- emissions of the chemical industry

2. Calculation of emissions:
    - Improvements of calculations methods
    - Calculation of actual emissions at national and regional level, for the year 2021
    - Update and optimisation of the emission estimates for the period 1995-2020
    - Update emission estimates for 1990

3. Compilation of emissions
    - Compilation of the detailed data for the sectoral calculations of emissions for all the relevant gases
    - Compilation of the relevant emission tables for the CRF Reporter

4. Uncertainty analysis for the year 2021, as well as update of the uncertainty analyses for 1995 and 2020

5. Reporting:
    - Drafting of the initial report, the interim report, and the final report
    - Presentations in the steering group meetings
    - Drafting of the contribution on fluorinated greenhouse gases for the National Inventory Report (methodology, information sources, recalculations made, uncertainty analysis, trend analysis)

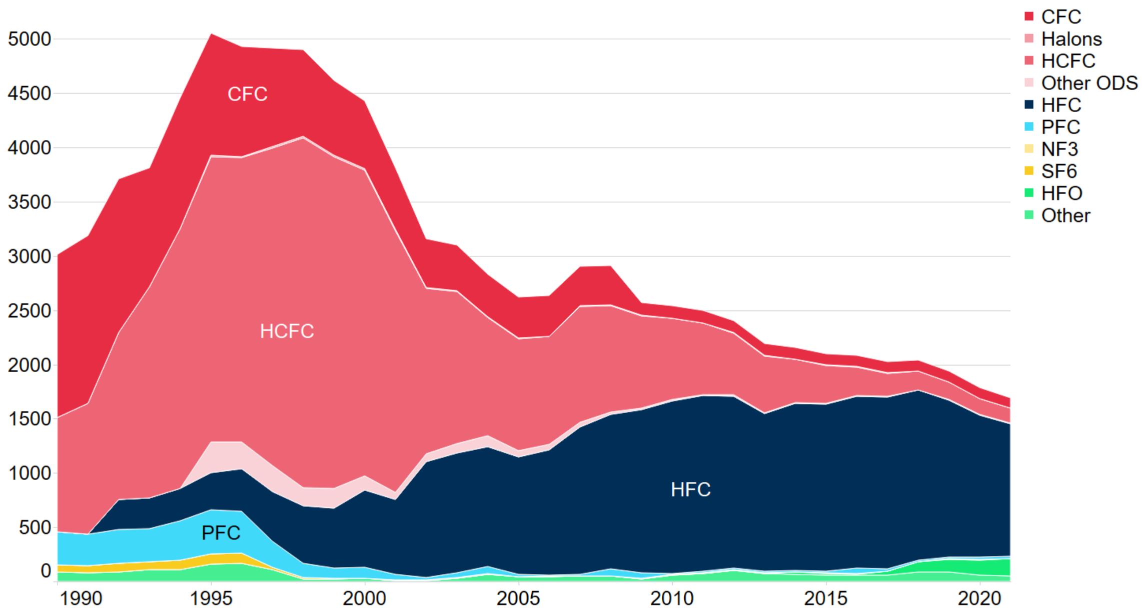
2 OVERALL RESULTS

In this chapter, results are shown on charts. Detailed data tables are provided in Annex 1.

2.1 Evolution of emissions by gas

Figure 2-1 shows the evolution of emissions in tonnes, in Belgium, by category of gas. The chart clearly shows the replacements of CFCs by HCFCs and later by HFCs.
The downward trend is continuing, more pronounced in the last three years.

Figure 2-1. Emissions of F-gases by type of gas in Belgium (in t).

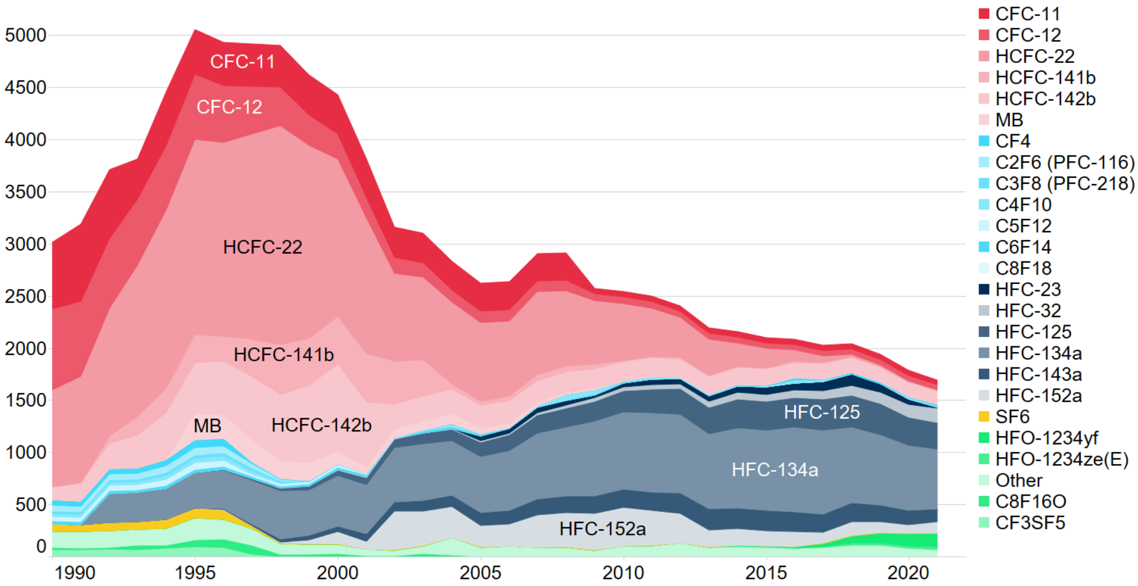


Source: VITO, Econotec (own calculations, 2022).

In 2021, the total emissions in tonnes have diminished by 4,9% compared to 2020. For the CRF F-gases, the corresponding decrease is 6,3%.

Figure 2-2 shows that while up to 2008 the main substance in tonnes used to be HCFC-22, it later became HFC-134a, with a growing share of HFC-125.

Figure 2-2. Emissions of F-gases by substance in Belgium (in t).



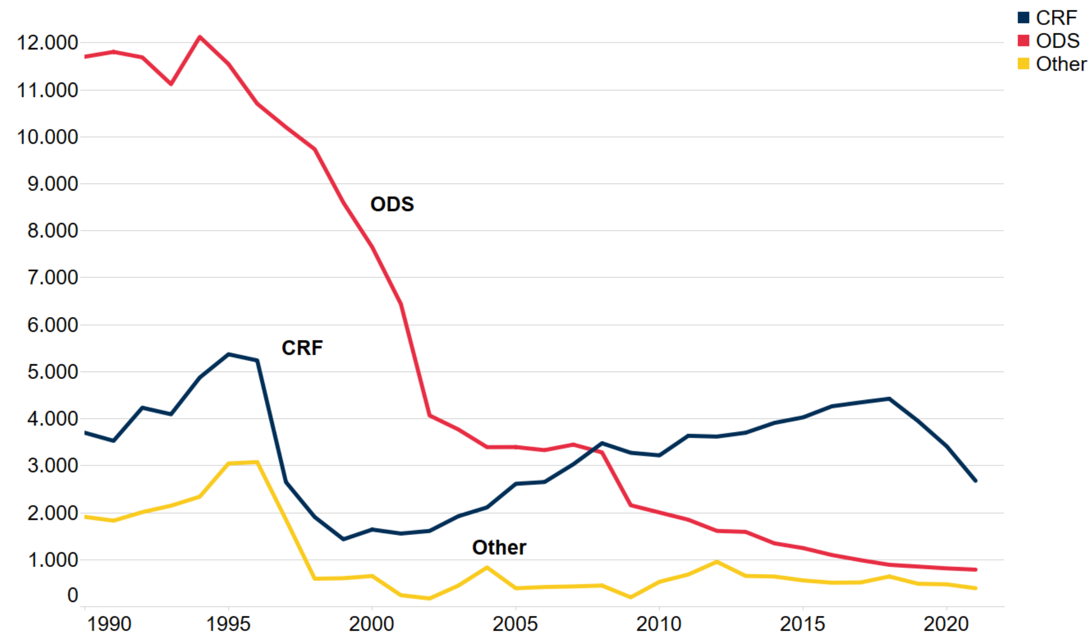
Source: VITO, Econotec (own calculations, 2022).

In terms of CO_2-equivalent, the emissions of ODS gases, which used to be the largest emission source, have strongly declined, as a result of the Montreal Protocol. The emissions of CRF F-gases, which partly replaced them, peaked in 2018 and continued to diminish in 2021 (Figure 2-3).

In 2021, total emissions decreased by 822 kt CO_2-eq (17,6%) compared to 2020. As in 2020, a large part of this reduction is due to HFC-23 (from the chemical industry). In 2021, HFC-23 was responsible for 61% of this decrease (505 kt CO_2-eq).

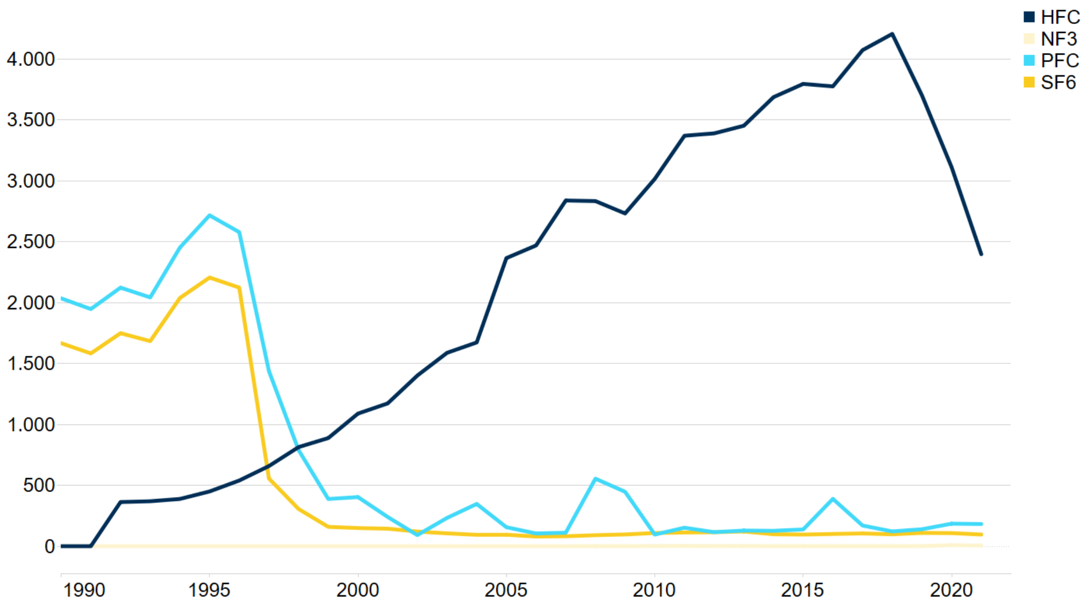
As shown on Figure 2-4, the bulk of CRF F-gas emissions is from HFCs.

Figure 2-3. Emissions of F-gases by gas category in Belgium (in kt CO_2-eq).



Source: VITO, Econotec (own calculations, 2022).

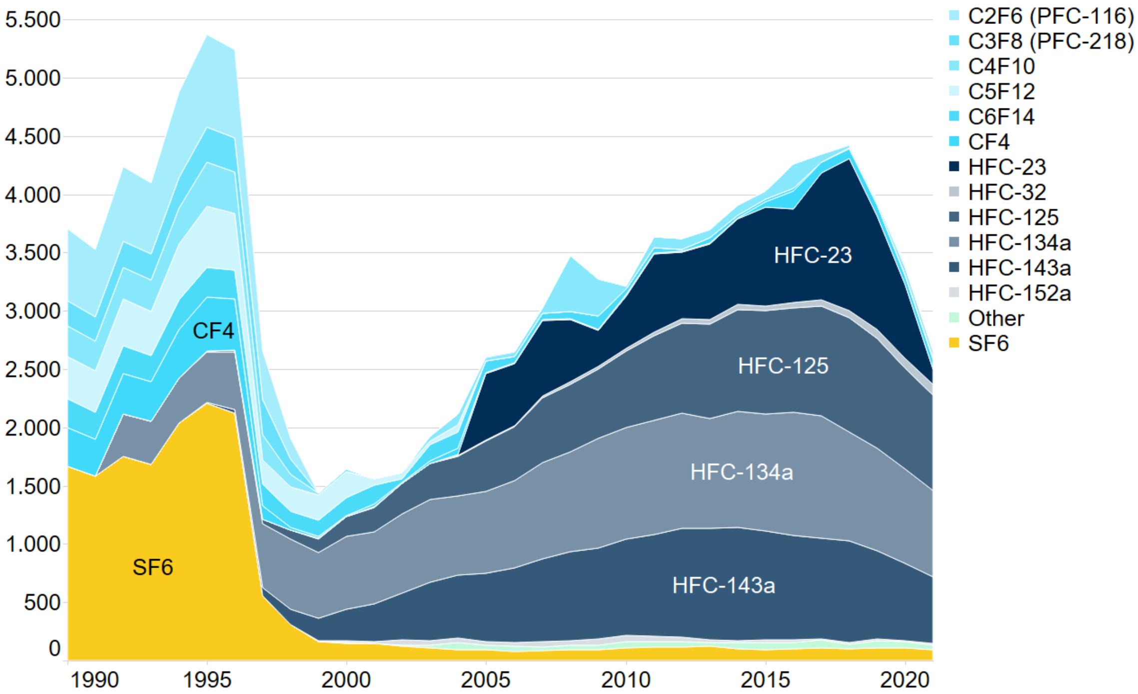
Figure 2-4. Emissions of CRF F-gases by gas category in Belgium (in kt CO_2-eq).



Source: VITO, Econotec (own calculations, 2022).

On Figure 2-5, notable is the predominance of 4 gases in the last decade: HFC-23, HFC-R143a, HFC-134a and HFC-125. The decrease since 2018 is mainly due to HFC-23, from the chemical industry. Although emissions of HFC-125, HFC-134a and HFC-143a have also gone down substantially.

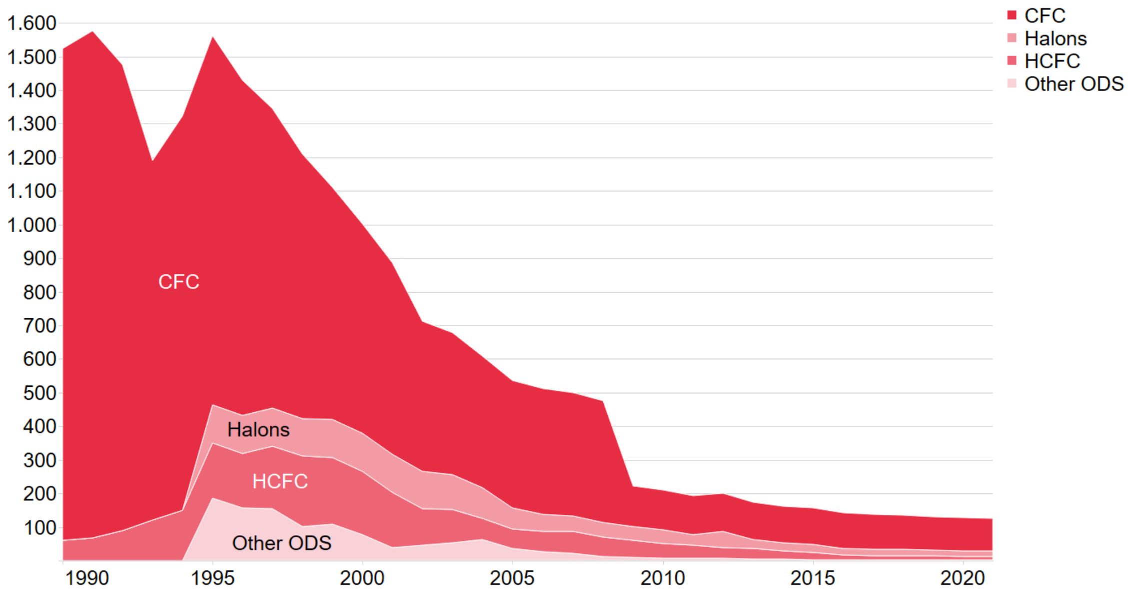
Figure 2-5. Emissions of CRF F-gases by substance in Belgium (in kt CO_2-eq).



Source: VITO, Econotec (own calculations, 2022).

The evolution of emissions of ozone depleting substances, expressed in tonnes CFC-11 equivalent, is shown Figure 2-6 (by gas category) and Figure 2-7 (by substance).

Figure 2-6. Emissions of ODS-gases by gas category in Belgium (t CFC-11-eq).

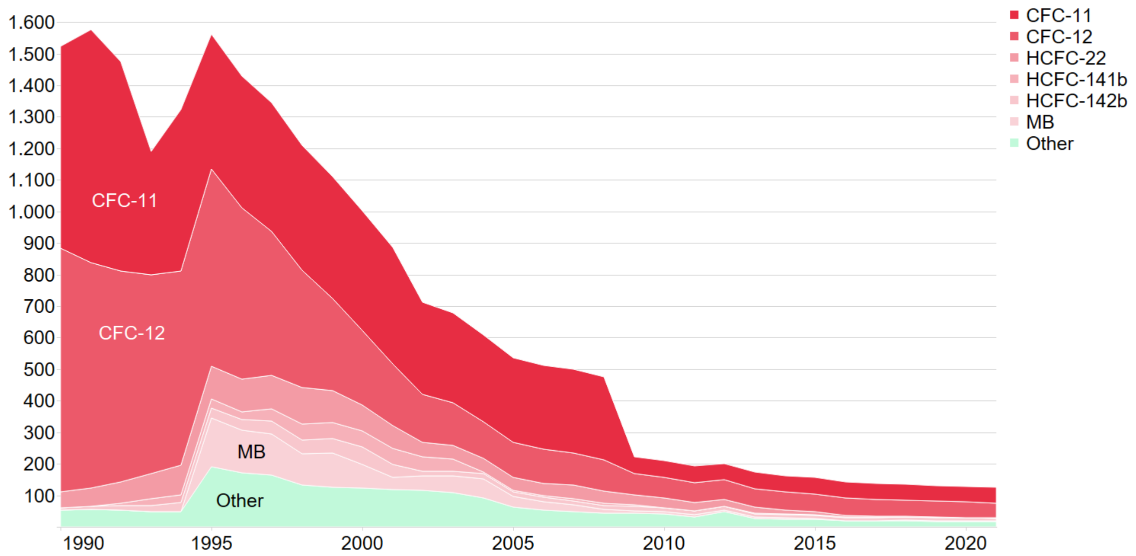


Source: VITO, Econotec (own calculations, 2022).

The drop in CFC-11 emissions between 2008 and 2009 is due to the disappearance of the stock of CFC-11 in household refrigerators and freezers, as modelled assuming an equipment lifetime of 15 years.

The major part of these emissions are CFC emissions, essentially emissions of CFC-11 and CFC-12 (see Figure 2-7).

Figure 2-7. Emissions of ODS-gases by substance in Belgium (t CFC-11-eq).



Source: VITO, Econotec (own calculations, 2022).

2.2 Evolution of emissions by source

When considering all gases and quantities in tonnes (Figure 2-8), stationary and mobile refrigeration and air-conditioning are the main emission sources, together with closed cell foams.

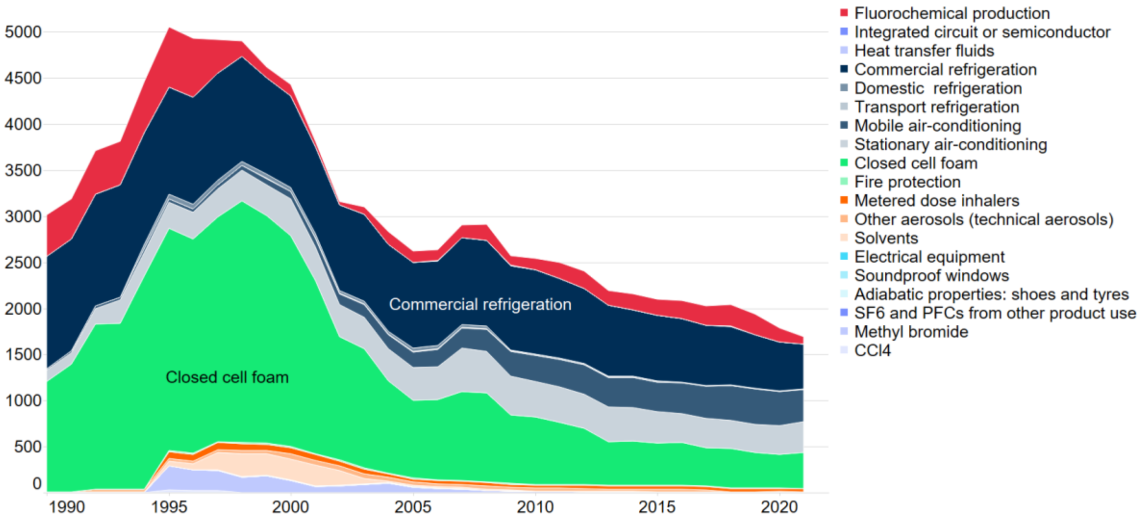
The decline in emissions essentially happens in commercial refrigeration (42 t or 125 kt CO_2-eq), fluorochemical production (66 t or 650 kt CO_2-eq) and mobile air-conditioning (17 t or 37 kt CO_2-eq) (Figure 2-9).

Table 2-1. Emissions of CRF F-gases by source (in kt CO_2-eq).

		2005	2010	2015	2020	2021
2.B.9.	Fluorochemical production	769	587	1077	840	275
2.E.1.	Integrated circuit or semiconductor	16	12	13	52	42
2.E.4.	Heat transfer fluids	0	0	0	0	0
2.F.1.a	Commercial refrigeration	1.183	1.669	1.847	1.437	1.293
2.F.1.b	Domestic refrigeration	1	2	2	1	1
2.F.1.d	Transport refrigeration	26	41	36	22	18
2.F.1.e	Mobile air-conditioning	220	369	419	342	305
2.F.1.f	Stationary air-conditioning	97	228	378	534	566
2.F.2.a	Closed cell foam	116	119	69	44	46
2.F.3.	Fire protection	13	14	14	11	10
2.F.4.a	Metered dose inhalers	36	42	45	44	44
2.F.4.b	Other aerosols (technical aerosols)	46	32	38	1	1
2.G.1.	Electrical equipment	12	16	11	11	8
2.G.2.c	Soundproof windows	72	89	81	74	71
2.G.2.d	Adiabatic properties: shoes and tyres	8	0	0	0	0
2.G.2.e	SF6 and PFCs from other product use	0	0	0	0	0
Total		**2.615**	**3.220**	**4.029**	**3.412**	**2.680**

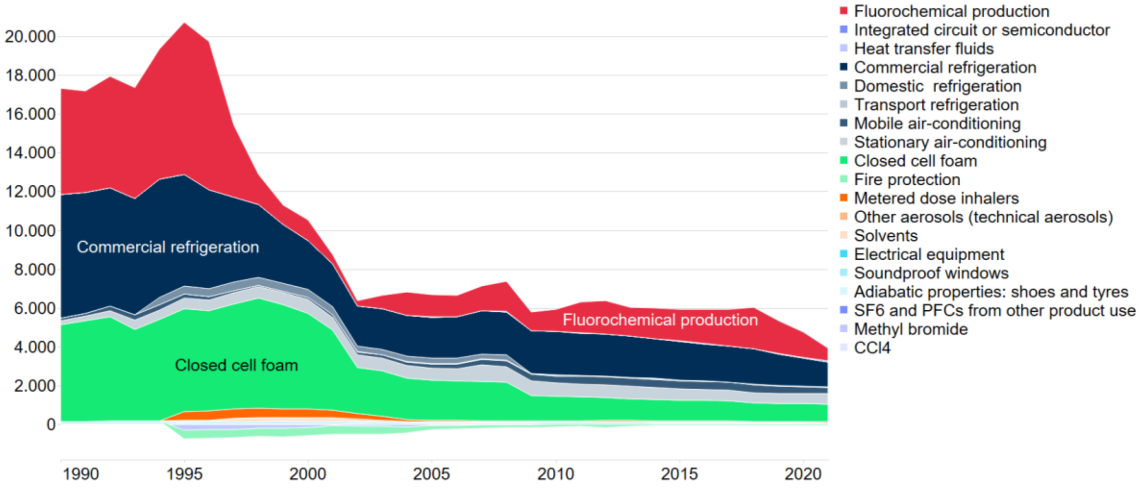
Source: VITO, Econotec (own calculations, 2022).

Figure 2-8. Emission of F-gases by source in Belgium (in t).



Source: VITO, Econotec (own calculations, 2022).

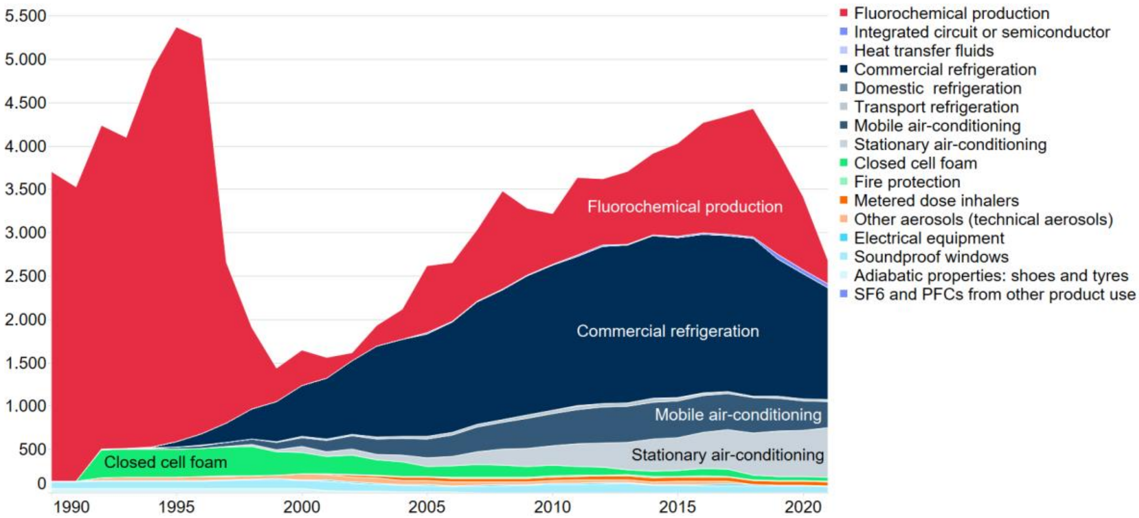
Figure 2-9. Emissions of F-gases by source in Belgium (in kt CO_2-eq).



Source: VITO, Econotec (own calculations, 2022).

When looking at CRF F-gases (Figure 2-10) emissions in CO_2-eq, there is a large increase up to 2018 followed by a strong decline, a trend that continues in 2021. The main sources are commercial refrigeration, fluorochemical production, mobile air-conditioning and stationary air-conditioning. Striking is the irregular pattern for Fluorochemical production.

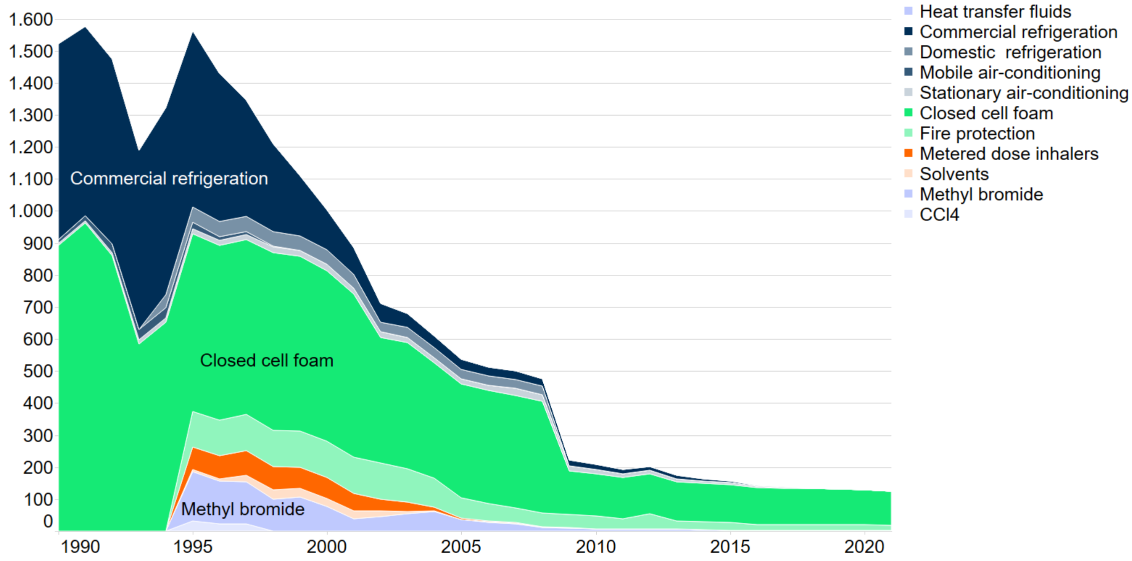
Figure 2-10. Emissions of CRF F-gases by source in Belgium (in kt CO_2-eq).



Source: VITO, Econotec (own calculations, 2022).

The ODS gas emissions, which fall under the Montreal protocol and are expressed in tonnes CFC-11-eq, have strongly declined (Figure 2-11), the main remaining share being that of closed cell foams (CFC-11 in polyurethane foams and CFC-12 in polystyrene foams).

Figure 2-11. Emissions of ODS-gases by source in Belgium (t CFC-11-eq).



Source: VITO, Econotec (own calculations, 2022).

3 IMPROVEMENTS AND RECALCULATIONS

3.1 Improvements

The following improvement efforts have been made:

- Bottom-up estimates of the consumption of R407C and R410A are lower than the annual supply of these refrigerants on the Belgian market. As these refrigerants are almost exclusively used for air-conditioning these remaining quantities are now allocated to the sector stationary air-conditioning (chillers) and not to commercial refrigeration as in the past.
- Commercial sealed refrigeration is added to the sector commercial and industrial refrigeration and not to the sector domestic refrigeration.
- Three new refrigerants added to the sector commercial refrigeration, i.e. R23, R452A and R513A (see section 4.4.1).
- Improvements in the calculation of emissions have been made for different sectors. See Table 3-1 and methodology sections in Chapter 4.
- Emissions from 1990 – 1994 included in the calculation tools.
- Emissions can be expressed in t and in kt CO_2-eq. based on AR4, AR5 and AR6 GWP.

3.2 Recalculations for 1990-2020

The recalculations that have occurred compared with the 2021 submission of the inventory to UNFCCC are listed in the table below.

Table 3-1. Overview of recalculations in period 1990-2020.

CRF code	CRF source category	Period	Nature of the recalculation	Impact for CRF gases in 2020 (in t)
2.E.1.	Integrated Circuit or Semiconductor	2018-2020	Adjusted SF6 emissions bases on input sector	3,1
2.F.1.a.	Commercial refrigeration	1992-1994 1996-2020	Emissions estimated and not equal to 1995. Change resulting from a reallocation of refrigerant consumptions between commercial refrigeration and stationary air-conditioning	-52,9
2.F.1.b	Domestic refrigeration	1992-1994 1996-2020	Emissions estimated and not equal to 1995. Hermetically sealed refrigeration allocated to commercial refrigeration	-5,7
2.F.1.d.	Refrigerated transport	1994 2018-2020	Emissions estimated and not equal to 1995. Adjustment of new registered vehicles as number was very low compared to total registrations of trucks	0,1
2.F.1.e.	Mobile air-conditioning	1992-1994 1996-2020	Emissions estimated and not equal to 1995. Manufacturing emissions updated based on data Audi. Error correction recharge emissions of cars. Adjustment assumption bus air-conditioning. Added agricultural and other vehicles.	3,8
2.F.1.f.	Stationary air-conditioning	1994 1997-2020	Emissions estimated and not equal to 1995. Added R407C and R410A emissions and included heat pump dryers and adjusted stock of movable air-conditioning based on latest household budget inquiry	63,6
2.F.2.a	Closed cell foam	2018-2020	Small correction for poly-urethena foam	0,0
2.F.3	Fire extinguishers	1993-1994	Emissions estimated and not equal to 1995.	-
2.F.4.b.	Technical aerosols	2020	Adjustment based on latest German inventory. Adjustment emissions 1990-1994.	-1,1
2.G.1	Electrical equipment	1990-1994	Emissions added.	-
2.G.2.c	Soundproof windows	1990-1994	Emissions added.	-
Total				**10,8**

CRF code	CRF source category	Impact for CRF gases in 2020 (in kt CO_2-eq AR4)	Impact for CRF gases in 2020 (in kt CO_2-eq AR5)
2.E.1.	Integrated Circuit or Semiconductor	34,6	33,1
2.F.1.a.	Commercial refrigeration	-64,9	-62,5
2.F.1.b	Domestic refrigeration	-14,4	-14,1
2.F.1.d.	Refrigerated transport	0,2	0,2
2.F.1.e.	Mobile air-conditioning	5,6	5,1
2.F.1.f.	Stationary air-conditioning	120,3	110,8
2.F.2.a	Closed cell foam	-0,1	-0,1
2.F.4.b.	Technical aerosols	-1,6	-1,5
Total		**79,9**	**71,0**

4 EMISSION INVENTORY BY SECTOR

4.1 Fluorochemical production (2.B.9.)

Introduction

The emissions of this source are those of an electrochemical synthesis (electro-fluorination) plant, which emits PFCs and HFCs, as well as fluorinated greenhouse gases not covered by the Kyoto Protocol. This plant produces a broad range of fluorochemical products, which are used as basic chemicals as well as end products, mainly in the electronics industry.

The processes used in this electro-fluorinated plant are unique within Europe (there are however some similar plants in the US). This means that there are no established guidelines for monitoring and reporting.

49 processes are considered, of which a minority are continuous processes and the remaining are batch ones. The emissions are partly ducted (those of the continuous processes and of most batch processes) and diverted to a thermal oxidizer, and partly non-ducted (the latter all from batch processes). The gas incinerator (thermal oxidizer) eliminates almost all the ducted emissions of the plant, but some CF_4-emissions nevertheless still occur. These are determined through measurements.

Methodology

For the non-ducted emissions, estimates are calculated by means of detailed material balances. For each process (all 49 processes for the greenhouse gas emissions) and for each component, an emission factor is established on an empirical basis. The emission factors are combined with detailed specific production data.

A full time series is given for all CRF greenhouse gases. The electrochemical plant has also provided emission data for other F-gases (not CRF), from 2005 onwards by substance, in t and kt CO_2-eq.

In 2015, the company reported that in 2014 it performed laboratory simulations of some specific production processes to better understand air emissions. These tests showed that HFC emissions could have been underestimated. This was already mentioned in previous inventory reports. To confirm the insights, local measurements on the related production processes were performed. These measurements confirmed the adjustments.

As part of the evaluation of these laboratory results, and in order to guarantee full transparency and reliability on the monitoring methodology of all processes and emissions, the company was requested to establish a monitoring plan that describes and evaluates in detail the calculation methods used for all F-gas emissions.

The drafting of the monitoring plan was performed in 2019. During that process, the company was assisted by an independent verification office (VBBV), appointed for that specific purpose by the Flemish Government because of its experience in monitoring EU

ETS emissions. Its assessments resulted *inter alia* in the acceptance of updates of some of the emissions factors used until then. The monitoring plan was finalized early 2020.

The Flemish government also requested the company to recalculate the historic emissions, taking into account the new insights and in accordance with the established monitoring plan. The company recalculated its emissions for the period 2005-2018, arguing that before 2005, multiple production processes at the chemical plant were run significantly different and therefore the updated emission factors would not be accurate for this period.

The recalculated emissions for 2005 and the period 2016-2018 were verified by the independent verification office (VBBV), while also a review of the recalculated 2006-2015 emissions was performed. These recalculated emissions are considered to be more valid and accurate than those reported in the past.

The recalculation exercise results in a substantial increase of emissions expressed in CO_2-eq compared to the previous inventory in 2020, especially for the CRF F-gases, because the new and more correct method results in higher emissions of CRF greenhouse gases and lower emissions of non-CRF greenhouse gases. It also changed the emission pattern. The revised emissions are shown by type of gas on Figure 4-1.

The company has taken further measures to monitor emissions more intensively and implemented mitigation measures to reduce emissions in the short term after 2018.

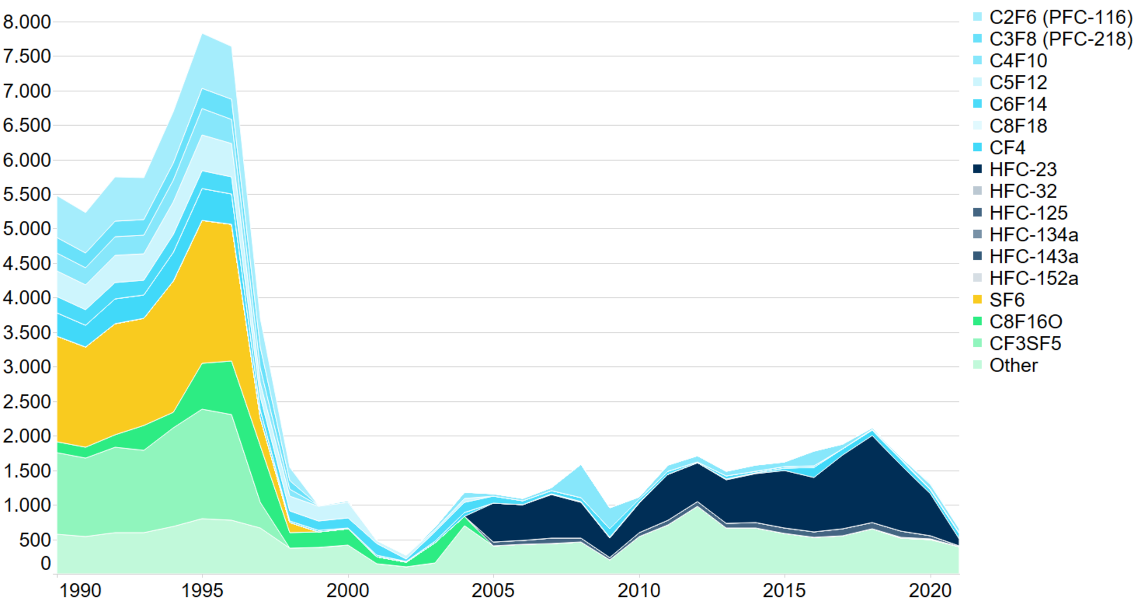
Results

The total and CRF emissions show two three different periods: high emissions in 1995 declining rapidly until 2002; slowly increasing emissions between 2002 and 2018; reducing emissions from 2018. From 2005 the emissions of HFC-23, a gas with a high GWP value, makes up a large share of total emissions of fluorinated greenhouse gases.

The mitigation measures already had an effect in 2019, with emissions below emissions in 2018. This trend continued in subsequent years. In 2021 emissions of CRF fluorinated greenhouse gases were reduced by 82% (or 1203 kt CO_2-eq) compared to 2018. Emissions of CRF fluorinated greenhouse gases in 2021 were 275 kt CO_2-eq, with HFC-23 and C4F10 as most important gases. Especially important to note is that the HFC-23 emissions have gone down substantially (92% or 1162 kt CO_2-eq).

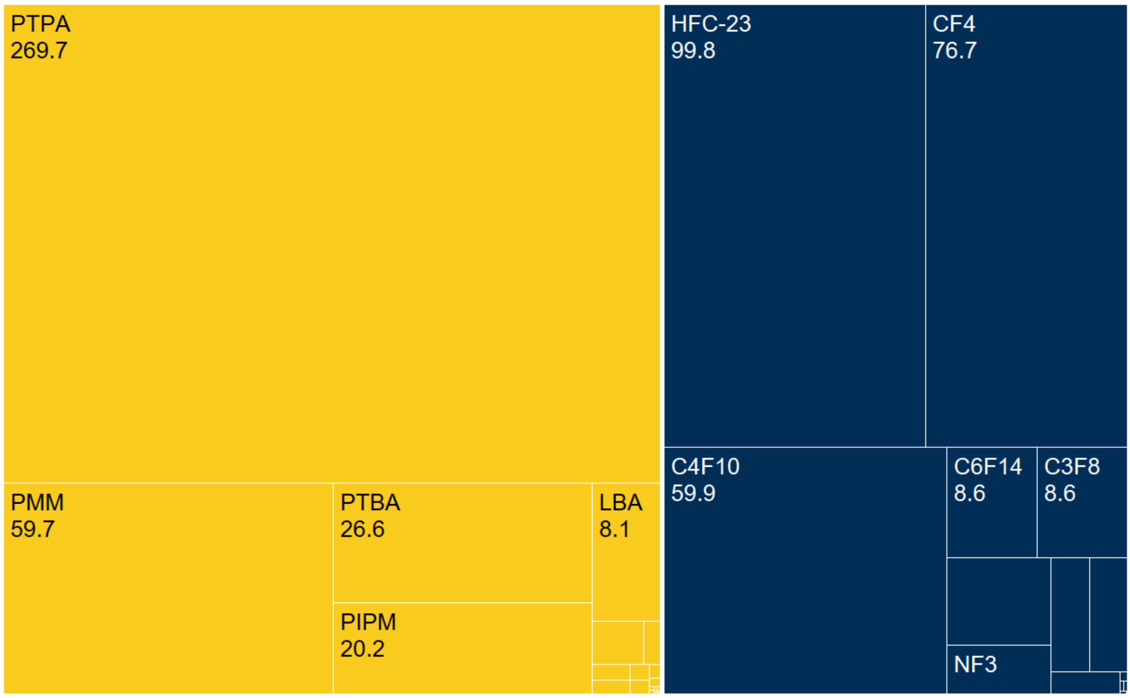
The pattern is somewhat different from non-CRF greenhouse gases. The decline has been less significant (39% reduction in 2021 compared to 2018). Emissions in 2021 were 388 kt CO_2-eq, mostly perfluorotributylamine (PTBA), perfluorotripropylamine (PTPA), perfluoromethyl morpholine (PMM) and LBA.

Figure 4-1. Emissions of F-gases from fluorochemical production (in kt CO_2-eq).



Source: VITO, Econotec (own calculations, 2022).

Figure 4-2. Emissions of F-gases from fluorochemical production in 2021 (in kt CO_2-eq).



Note: Blue are CRF gases, orange are non-CRF and non-ODS gases

Source: VITO, Econotec (own calculations, 2022).

Table 4-1. Emissions of key F-gases from fluorochemical production in 1990-2021 (in kt CO_2-eq).

	1990	1995	2000	2005	2010	2015	2020	2021
CRF	**3.568**	**4.783**	**403**	**769**	**587**	**1.077**	**840**	**275**
PFC	**2.035**	**2.716**	**403**	**140**	**81**	**130**	**156**	**157**
CF4	330	459	7	5	10	40	57	77
C2F6	611	797	0	0	0	0	7	4
C3F8	217	297	0	0	0	0	17	9
C4F10	264	385	18	36	24	71	67	60
C5F12	366	519	226	0	0	0	0	0
C6F14	246	260	152	99	47	19	8	9
HFC	**0**	**0**	**0**	**630**	**505**	**947**	**674**	**112**
HFC-23	0	0	0	564	434	829	604	100
Other	0	0	0	65	72	117	70	12
SF6	**1.533**	**2.067**	**0**	**0**	**0**	**0**	**3**	**1**
NF3	**0**	**0**	**0**	**0**	**0**	**0**	**7**	**4**
Other	**1.911**	**3.048**	**653**	**391**	**523**	**548**	**473**	**388**
CF3SF5	1.183	1.581	0	0	0	0	0	0
C8F16O	159	667	241	0	0	0	0	0
PTPA	0	0	0	114	121	123	272	270
PMM	0	0	0	166	97	255	79	60
PTBA	0	0	0	43	50	31	41	27
PIPM	0	0	0	0	57	55	19	20
LBA	0	0	0	68	183	61	58	8
Other	569	799	412	1	14	24	4	4
Total	**5.479**	**7.831**	**1.056**	**1.161**	**1.110**	**1.625**	**1.313**	**663**

Source: VITO, Econotec (own calculations, 2022).

4.2 Integrated Circuit or Semiconductor (2.E.1.)

Introduction

The semiconductor industry currently emits PFCs (CF4, PFC-116, PFC-218, c-C4F8), HFC (HFC-23, HFC-32, HFC-41, HFC-125), nitrogen trifluoride (NF3) and sulphur hexafluoride (SF6) from production processes. These gases are used for etching structures on thin insulating and metal layers and for cleaning reaction chambers following chemical vapour deposition (CVD). The FFCs allow manufacturers to accurately etch the submicron-scale patterns on these metal and dielectric layers and perform rapid chemical cleaning of CVD tool chambers. The carbon and fluorine that these compounds deliver in a plasma are essential when etching advanced integrated circuits because, in addition to etching, they form polymers, which allow for highly selective and anisotropic (directional) film removal [1]. In the production process, some of the PFCs fed into plasma chambers are converted partly into CF4.

The semiconductor industry's emissions depend partly on the degree to which the industry uses waste-gas-scrubbing equipment. They also depend directly on semiconductor-production levels (in the present case, annual levels). As a result of these dependencies, emissions tend to fluctuate from year to year.

In printed circuit board (PCB) production, drilled holes are cleaned with systems that use CF4. As a repeat survey carried out in 2019 found, this area of application undergoes few changes.

Methodology

Photovoltech reported in previous years that no fluorinated greenhouse gases were used in their production process. Semiconductor manufacturers also reported the quantities of fluorinated greenhouse gases used, including NF3. We also requested information specifically on heat transfer fluids.

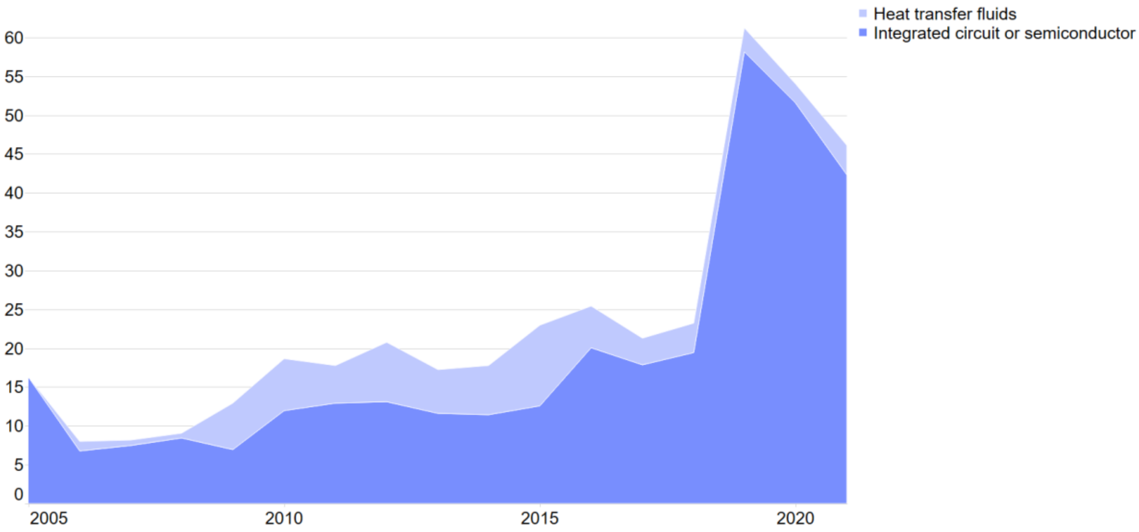
As an activity variable, the number of photomoves could be considered. One company provided this information, which corresponded well with the emissions. Although this activity variable is not useful to characterise the activities of research centres rather than production sites, there is a good correlation between the total emissions by this sector and the number of photomoves.

Data on consumption and emissions are collected from the companies concerned. For the period 2019-2021 emissions were adjusted because of a revised emission calculation method by one company. Recalculation of emissions was not possible for previous years. Mitigating measures have been implemented since then.

Results

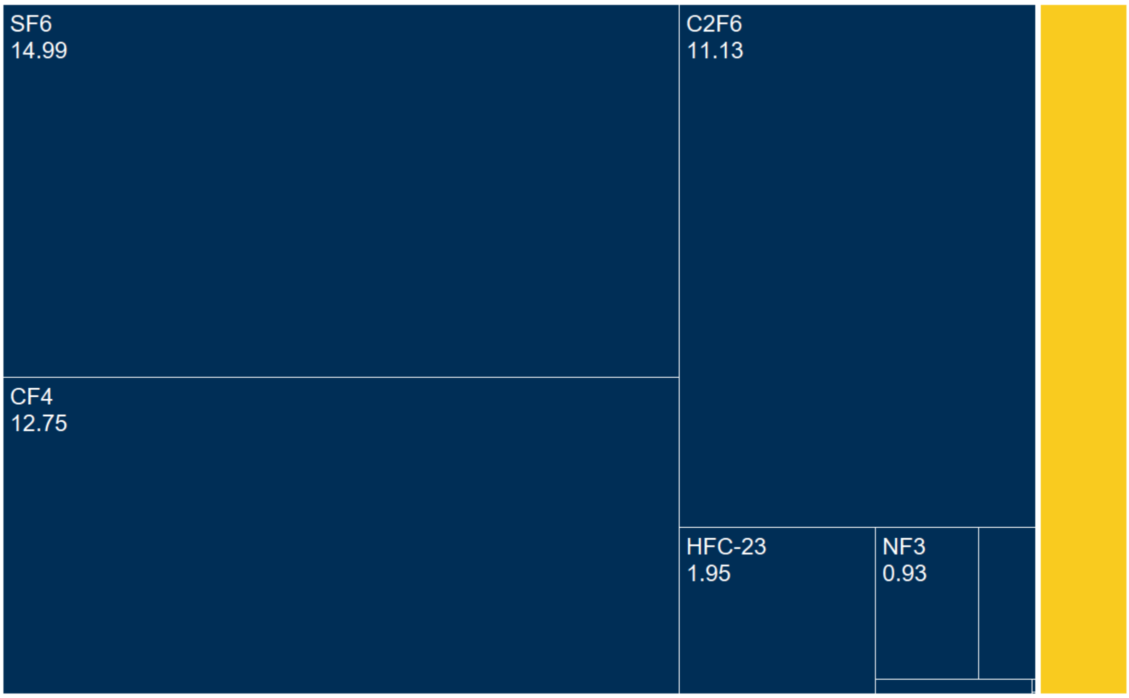
The recalculation resulted in an increase in emissions in 2019 compared to previous years, especially for SF6. In 2021, emissions have declined again albeit not to the same level as in 2018 (Figure 4-3). Emissions of semiconductor production in 2021 are dominated by SF6 (35%), CF4 (30%) and C2F6 (26%).

Figure 4-3. Emissions of F-gases from semiconductor industry and heat transfer fluids in Belgium (in kt CO_2-eq).



Source: VITO, Econotec (own calculations, 2022).

Figure 4-4. Emissions of F-gases from semiconductor industry in Belgium in 2021 (in kt CO_2-eq).



Source: VITO, Econotec (own calculations, 2022).

4.3 Heat transfer fluid (2.E.4.)

Introduction

PFCs are used as heat transfer fluids (HTFs) in commercial and consumer electronic applications. The various applications of PFC as HTFs use much smaller volumes of liquid PFCs than electronics manufacturing. Some examples of consumer applications include cooling kits for desktop computers and commercial applications include cooling supercomputers, telecommunication, and radar systems, as well as drive units on high-speed trains. The emission data are retrieved from the semi-conductor industry, for which this is relevant and results are included there. Total emissions in 2021 for heat transfer fluids were estimated to be 3,8 kt CO_2-eq, including emissions of ODS and other fluorinated greenhouse gases.

4.4 Refrigeration and air-conditioning equipment (2.F.1.)

HFCs have been introduced and widely used as replacement for CFC and HCFC refrigerants in commercial, industrial and domestic refrigeration and in stationary and mobile air-conditioning.

Emissions can occur at different stages of the lifecycle of refrigeration/air-conditioning equipment:

- During the refrigeration equipment manufacturing process (for hermetically-sealed equipment);

- During the on-site installation and filling of equipment;
- Over the operational lifetime due to regular and accidental releases; and
- At disposal of the refrigeration or air-conditioning unit on site or at diposal facility.

For the refrigeration sector, emissions have been estimated separately for the following source categories:

- industrial and commercial refrigeration installations,
- household hermetic refrigerators,
- chillers, room air-conditioners, heat pumps, and tumble dryers,
- air-conditioning of veicles: private cars, buses and coaches, trucks air-conditioning, passenger rail transport, and other vehicles,
- refrigerated transport.

In accordance with the IPCC guidelines, the assembly emissions, the emissions during lifetime and the disposal emissions are being determined separately. For each substance, the assembly emissions are calculated as a function of the estimated amount charged into new systems and the percentage assembly losses, the emissions during lifetime as a function of the amount stocked in existing systems and assumptions on annual leakage rates, and the disposal emissions in function of the amount in systems at time of disposal and the estimated recovered fraction.

4.4.1 Commercial refrigeration (2.F.1.a.)

Introduction

As industrial refrigeration installations could not be evaluated separately from commercial refrigeration, under the source category Commercial refrigeration (2.F.1.a.) are reported all on-site assembled systems for industrial and commercial refrigeration and hermetically-sealed commercial refrigerators and freezers.

Methodology

- **On-site assembled systems for industrial and commercial refrigeration**

The stock and the emissions of refrigerants are modelled using a mass-balance approach, based on the annual supply of refrigerants. The latter is obtained from an annual inquiry among refrigerant suppliers on their national supply of each refrigerant mixture. The estimated supply for refilling vehicles' air-condioners (cars, buses and coaches, trucks, passenger rail transport), refrigerated transport and stationary air-conditioning devices is subtracted. Assumptions are made on the average loss rates. The reason why no distinction is made between industrial refrigeration and commercial refrigeration installations is that it is not possible to disaggregate the refrigerant consumption data between these sub-sectors, because of the presence of intermediary wholesalers, and the fact that no inventory of installations is available.

The annual operation and servicing emissions are estimated as the amount of refrigerant banked in existing systems at the end of the previous year, times an annual leakage rate (see below). Where for each refrigerant the bank at the end of each year is calculated by a mass balance from the bank at the end of the previous year. The mass balance ensures that the overall emissions are consistent with the amounts of refrigerants sold on the market.

The disposal emissions are calculated, using equation 7.14, page 7.51 of the 2006 IPCC Guidelines (IPCC, 2006), as the amount initially charged into new systems times the percentage residual charge, times one minus the recovery efficiency at disposal.

Equation: Emissions at end of life

$$E_{end\ of\ life,t} = M_{t-d} \times \frac{p}{100} \times \left(1 - \frac{\eta_{rec.d}}{100}\right)$$

$E_{end\ of\ life,t}$ = amount of HFC emitted at time of disposal in year t, kg

M_{t-d} = amount of HFC initially charged into new systems installed in year (t − d), kg

d = lifetime

p = residual charge of HFC in equipment being disposed of expressed in percentage of full charge, %

$\eta_{rec,d}$ = recovery efficiency at disposal, which is the ratio of recovered HFC to the HFC contained in the system, %

The percentage residual charge p is assumed to be 70%, and the lifetime 15 years (which is an average).

For the time being, we have kept for the recovery efficiency of disposal a fixed value of 25% (except for the disposal from retrofitting, for which the recovery rate has been assumed to be 50%, as it is more likely to be carried out by certified technicians). This figure is justified as follows. Figures on recovery of fluorinated gases are available from surveys among the companies authorized to collect such gases, carried out annually by ECONOTEC-VITO in the framework of the updating of the F-gas emission inventory. The main reason why these figures have not been used directly for calculating disposal loss factors (ratios “disposal emissions”/”amount in systems at time of disposal”) is that the “amount in systems at time of disposal” is only estimated by modelling, based on simplified assumptions (such as a common lifetime of installations, equal to the average lifetime). If the annual data of recovered fluorinated gases were used, the calculation could sometimes lead to unrealistic values (e.g., larger than 100%) of disposal loss factor for individual years.

In 2020 and 2021, no increase has been observed in the amounts of recovered refrigerant, nor in the average recovery rate. An order of magnitude of disposal loss factor can be obtained by comparing the sum over time of the recovery figures with the sum over time of the “amount in system at time of disposal”. The average recovery rate of HFCs – including the ‘Stationary air-conditioning’ sector and estimated as described – over the period 1998-2021 is 25,5%.

The 25% recovery factor may be considered as a conservative value, tending to overestimate the emissions rather than underestimate them, as some players have stored recovered R404A or R507A for use in future maintenance of other installations. However, the quantities concerned are unknown, and on the other hand an underestimation of emissions arises because of the fact that these recovered quantities are not taken into account in the overall consumption of refrigerants. Another source of unquantified underestimation is related to illegal trade.

- **Hermetically-sealed**

Commercial refrigerators include also all hermetically sealed refrigerators, used most frequently in retail food stores. Unlike the category industrial and commercial refrigeration, these are not filled when installed, but are prefilled with refrigerants. Because no statistics are available differentiating between hermetically sealed commercial refrigeration types, no distinction is made.

The number of new hermetically sealed commercial refrigerators is calculated based on the number of supermarkets and smaller shops in Belgium from 1995 to 2019. Statistics were used from Nielsen [7] and published statistics from STATBEL. Equipment in smaller shops, e.g., food retail, restaurants, hotels, etc., were included from the 2018 inventory. Assumptions on the use (kg) of refrigerants in hermetically sealed refrigeration per shop (depending on its size) were taken from the literature. Overall, the load per equipment is assumed to be 500 g on average. The most frequently used refrigerants are HFC-134a and R404A. The shares of each have changed over the years, with an increasing use of non-HFC refrigerants and decreasing shares of R404A because of its high GWP. The time series was reconstructed based on the available literature and inventories from France and the UK.

The annual emission factor for hermetically sealed commercial refrigerators and freezers is 1%, irrespective of the type (refrigerator, freezer, and combination) (see IPCCC methodology below).

Commercial refrigeration has an average lifetime of 10 years. With respect to disposal, commercial refrigeration is in some cases collected via the Recupel system. For calculating the disposal emissions, the same assumptions were used as for domestic appliances. The study [8] showed that emissions from commercial hermetically sealed refrigeration that is dismantled correctly are very limited. There is however a large uncertainty related to the number of refrigerators that are disposed correctly and those that are disposed incorrectly with high emissions as a result.

Table 4-2. Comparison of assumptions for hermetically sealed commercial refrigerators between selected countries.

Assumption	Belgium	France	Germany	UK
Disposal EF (%)	37%	76%	40%	66%
Operational EF (%)	1%	1%	1% - 1,4%	2%
Manufacturing EF (%)	NO	NA	NA	1%
Lifetime (y)	10	15	10	15
Charge (kg)	0,5	0,3 – 2,8 per store	NA	0.2 - 1

Source: Information taken from NIR (HTTPS://UNFCCC.INT/GHG-INVENTORIES-ANNEX-I-PARTIES/2022).

Table 4-3. Assumptions for hermetically sealed commercial refrigerators and comparison with IPCC 2006 guidelines.

	Belgium	2019 refinement
Charge (kg)	0.5	0.2 < M < 6
Lifetime (y)	10	10 < d < 15
Manufacturing EF (%)	NO	0.5% < EF < 3%
Operational EF (%)	1%	1% < EF < 15%
Recovery efficiency (%)	63%	0% < RE < 70%

Source: VITO, Econotec (2022), IPCC [2].

- **Survey on the supply of refrigerants**

As for the previous updates of the emission inventory, a survey of the supply of refrigerants in Belgium[2] was carried out among the 7 importers/wholesalers. All the companies have responded. The results up to 2021 are shown in Table 4-6. The composition of the refrigerants is given in Annex C.

Despite the strong EU HFC quota reduction (from 63% in 2020 to 45% in 2021[3]), the latest survey shows a rebound in sales of 10,7% in 2021, likely related to the economic recovery after the 2020 recession (GDP rose by 6,2% in 2021, after a 5,7% downturn in 2020).

The increase in 2021 is mainly R410A (stationary air-conditioning), R449A and R1234yf (mobile air-conditioning). But there is also a rise for R404A, of which the prices have tumbled after their peak in 2018 (Figure 4-5 and Figure 4-6).

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2 Excluding the supply to Original Equipment Manufacturers (OEM), which are covered separately).
3 Art. 15 of EU Regulation 517/2014.

Table 4-4. Supply of fluorinated refrigerants in Belgium (in t).

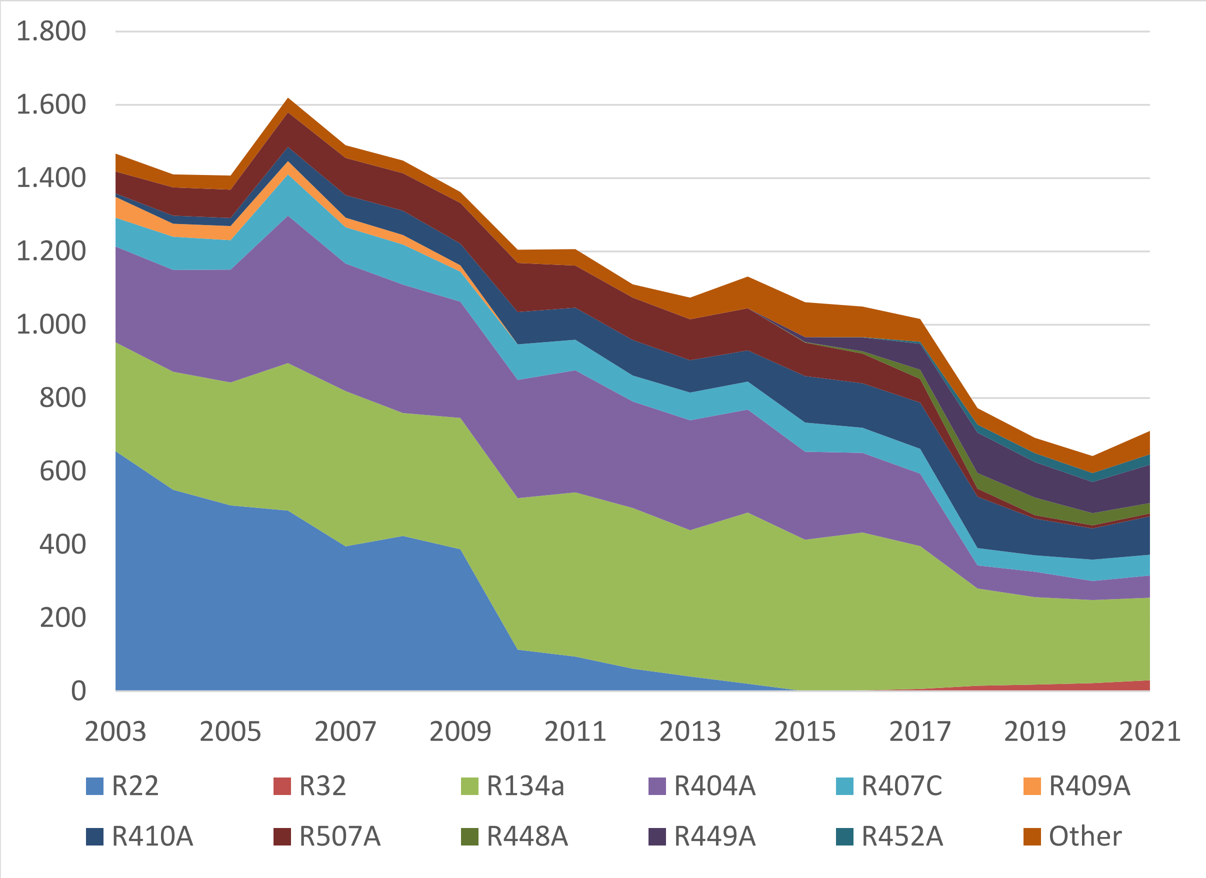
(tonnes)	2003	2005	2010	2013	2015	2016	2017	2018	2019	2020	2021
HCFC	**712,1**	**545,3**	**113,5**	**40,0**	**0,0**	**0,0**	**0,0**				
R22	655,2	506,6	113,5	40,0	0,0	0,0	0,0				
R123 (*)	0,0	0,0	0,0	0,0	0,0	0,0	0,0				
R124 (*)	0,0	0,3	0,0	0,0	0,0	0,0	0,0				
R409A	56,9	38,3	0,0	0,0	0,0	0,0	0,0				
HCFC-HFC	**32,6**	**23,5**	**0,0**	**0,1**	**0,0**	**0,0**	**0,0**				
R401A	7,3	3,6	0,0	0,0	0,0	0,0	0,0				
R402A	2,4	2,0	0,0	0,0	0,0	0,0	0,0				
R403B	1,3	1,7	0,0	0,0	0,0	0,0	0,0				
R408A	21,6	16,1	0,0	0,1	0,0	0,0	0,0				
HFC	**709,7**	**831,4**	**1.090,3**	**1.031,4**	**1.042,3**	**996,4**	**907,3**	**582,7**	**502,7**	**473,3**	**511,5**
R23 (*)	4,2	4,1	0,6	4,6	2,5	1,5	2,1	0,7	0,6	1,2	6,4
R32	0,0	0,0	0,0	0,0	0,0	2,5	6,3	14,6	18,2	21,7	29,7
R134a	296,6	335,3	413,2	399,3	413,4	430,5	389,7	265,5	238,1	226,6	224,8
R404A	261,0	308,5	322,2	300,0	240,0	216,9	197,5	62,8	69,1	52,6	60,9
R407A	0,0	0,0	0,0	1,0	0,8	1,8	1,1	0,5	0,9	0,1	2,2
R407C	79,0	80,2	96,9	75,3	79,6	69,1	67,6	47,8	45,4	57,7	56,5
R407F	0,0	0,0	0,0	9,1	40,1	38,4	27,4	15,3	11,2	12,6	11,3
R407H								0,0	0,0	0,0	0,0
R410A	9,2	22,1	88,2	88,3	126,4	121,2	125,7	139,6	100,2	85,2	105,2
R417A	0,0	3,9	11,1	13,4	5,9	3,4	3,5	1,6	0,9	0,9	0,6
R422A	0,0	0,0	0,0	3,1	3,1	1,7	0,8	0,4	0,4	0,4	0,2
R422D	0,0	0,0	16,8	18,7	28,2	23,7	14,2	6,1	7,4	3,7	1,7
R427A	0,0	0,0	7,5	6,7	7,1	4,0	4,3	3,4	0,9	2,0	4,2
R434A	0,0	0,0	0,0	0,0	4,0	0,0	1,3	1,8	0,1	0,0	0,0
R437A	0,0	0,0	0,0	0,0	0,0	0,5	0,1	0,1	0,0	0,0	0,0
R438A						0,3	0,4	0,4	0,1	0,0	0,0
R507A	59,7	77,2	133,7	112,1	91,2	81,0	65,1	22,4	9,3	8,6	7,7
HFC-PFC	**12,3**	**6,4**	**0,9**	**0,3**	**0,0**	**0,1**	**0,0**	**0,2**	**0,1**	**0,0**	**0,0**
R413A	12,3	6,4	0,9	0,3	0,0	0,1	0,0	0,2	0,1	0,0	0,0
R508B	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
HFC-HFO	**0,0**	**0,0**	**0,0**	**0,0**	**16,0**	**44,4**	**103,0**	**179,1**	**179,7**	**155,0**	**173,2**
R448A	0,0	0,0	0,0	0,0	2,0	6,0	24,7	42,1	48,1	32,8	28,3
R449A	0,0	0,0	0,0	0,0	13,0	37,6	70,9	110,2	97,0	85,3	104,4
R450A	0,0	0,0	0,0	0,0	1,0	0,0	0,5	2,1	1,1	1,1	0,5
R452A	0,0	0,0	0,0	0,0	0,0	0,9	6,1	22,0	24,0	24,1	28,6
R453A											0,2
R454A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,0	0,0	0,0
R454B								0,0	0,1	1,0	0,1
R454C	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,0	1,0	0,2
R455A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,2	1,0
R513A	0,0	0,0	0,0	0,0	0,0	0,0	0,8	2,6	9,4	8,4	9,8
HFO	**0,0**	**0,0**	**0,0**	**2,0**	**2,4**	**8,4**	**5,5**	**9,8**	**8,6**	**12,8**	**25,2**
R1234yf	0,0	0,0	0,0	2,0	2,4	6,9	4,5	8,9	7,3	11,2	22,0
R1234ze(E)	0,0	0,0	0,0	0,0	0,0	1,5	1,1	0,9	1,1	1,6	3,2
R1336mzz(Z)									0,1		
Total général	**1.466,7**	**1.406,5**	**1.204,8**	**1.073,8**	**1.060,8**	**1.049,2**	**1.015,8**	**771,9**	**691,1**	**641,1**	**709,9**

Excluding supply to original equipment manufacturers (OEM)

(*) Up to 2013 not necessarily complete

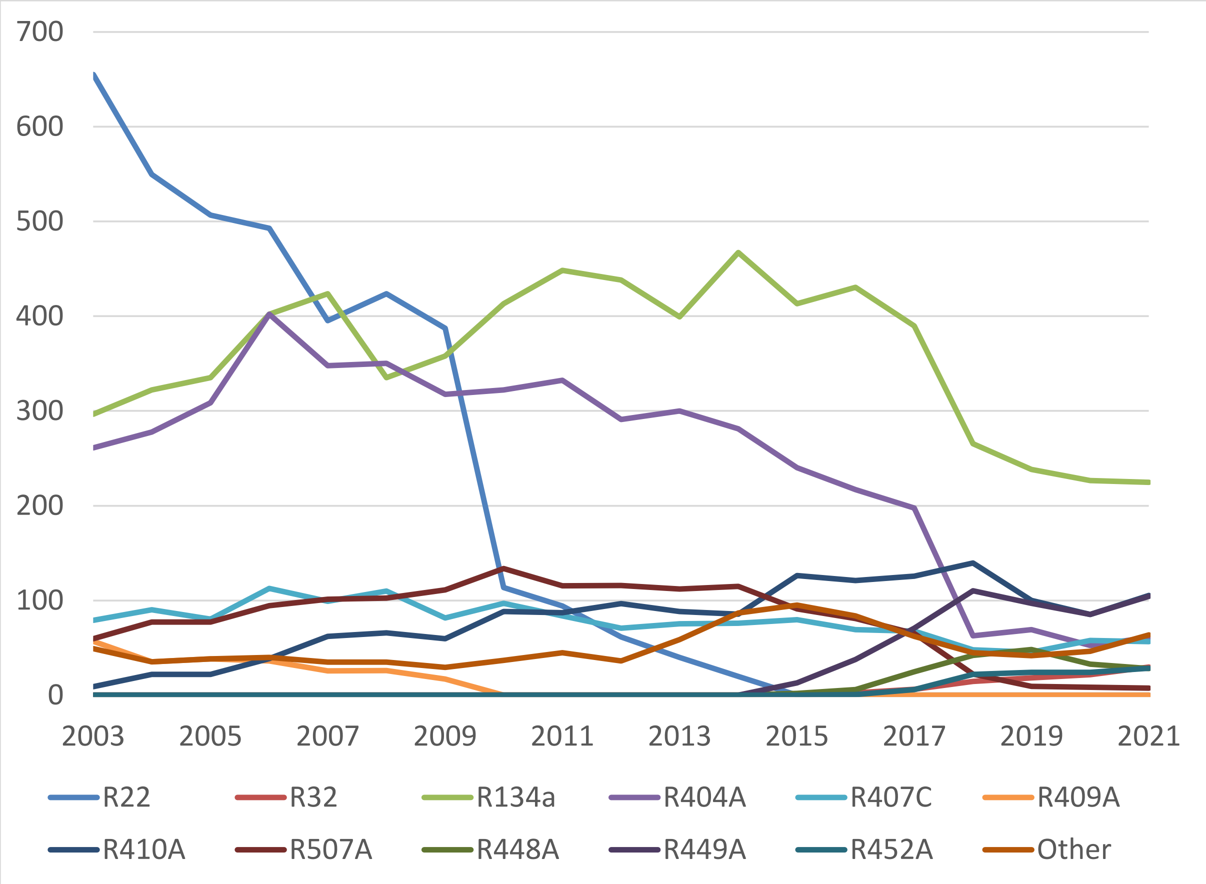
Source: VITO, Econotec (survey, own calculations, 2022).

Figure 4-5. Supply of fluorinated refrigerants in Belgium (in t).



Source: VITO, Econotec (survey, own calculations, 2022).

Figure 4-6. Supply of fluorinated refrigerants in Belgium, by refrigerant (in t).



Source: VITO, Econotec (survey, own calculations, 2021).

- **Annual leakage rate**

As for every update, an assumption must be made about the average yearly leakage rate of the "installations". The assumptions made and their rationale are as follows.

For up to 2004, we had assumed a constant bank[4] and a constant emission rate from the refrigerant bank. However, there has been a significant decrease in the total consumption of refrigerants, confirmed by the results of the survey. It is likely that because of the EU regulations on CFC and HCFC refrigerants, and EU Regulation 517/2014 on fluorinated greenhouse gases, the regional policies and measures, as well as of the higher prices of the new HFC based refrigerants, the emission rates (the losses) have decreased on average.

Evidence of the decrease can be found in the results of the inspection campaigns carried out on refrigerant plants in Flanders up to 2016[5] (see Table 4-2 and Figure 4-7).

[4] The assumption of a constant bank had originally been made because the refrigerant supply statistics of UBF/ACA were incomplete for the years up to 1993. Therefore, for these years only the proportions of the various refrigerants in the supply were being used.

[5] 2016 is the latest year for which such data are available. Many cooling plants are in use in 'Class 2 companies', which means that they are now more and more being controlled by municipalities.

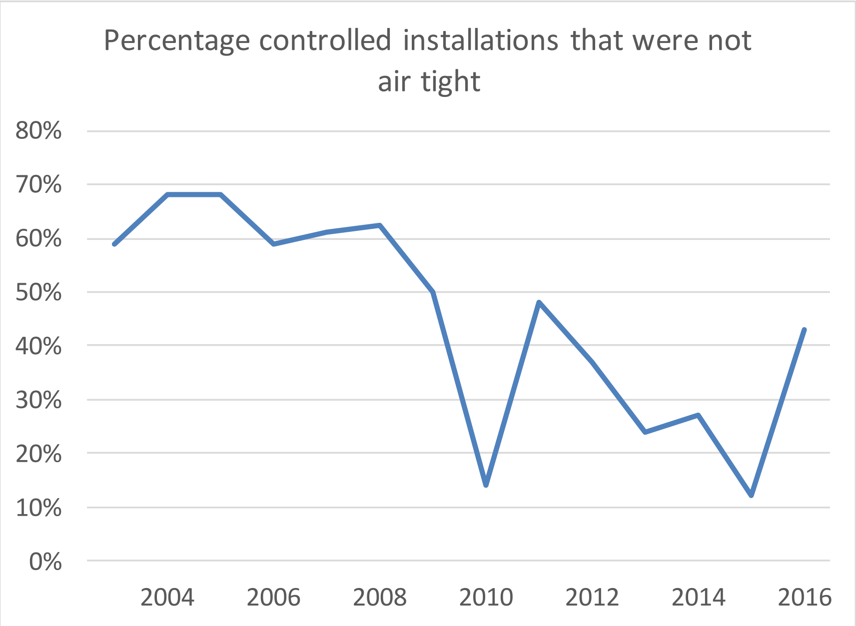
Leakages still occur at a significant fraction of the investigated plants (in 2016, 43% of the inspected plants still had leakages), but there has on average been a decreasing trend over the last 8 years. It should be noted that the installations concerned are not necessarily representative of the existing stock of installations and that inspections have tended to focus on plants that are more likely to be leaking.

Table 4-5. Results of inspection campaigns on refrigeration plants in Flanders.

	Cooling systems tested on behalf of Milieu-inspectie	
	Number of installations	Not airtight
2016	139	43%
2015	141	12%
2014	151	27%
2013	178	24%
2012	154	37%
2011	72	48%
2010	164	14%
2009	157	50%
2008	220	62%
2007	248	61%
2006	272	59%
2005	238	68%
2004	130	68%
2003	123	56%

Source: Milieuhandhavingsrapport Afdeling Milieu-Inspectie (for the years 2003-2016).

Figure 4-7. Percentage controlled installations that were not air-tight in Flanders.



Source: Milieuhandhavingsrapporten Afdeling Milieu-Inspectie, own calculations.

Table 4-6. Leakage by refrigerant on refrigeration plants in Flanders in 2016.

	Number of inspected installations	Number of leaking installations	Leaking installations (%)
R22	**8**	**7**	**88%**
R507 and R507A	**27**	**13**	**48%**
R404A	**24**	**15**	**62%**
R134a	**38**	**21**	**55%**
R407 + R407C	**42**	**4**	**10%**
Total	**139**	**60**	**43%**

Source: Milieuhandhavingsrapporten Afdeling Milieu-Inspectie (2016).

Unsurprisingly, the percentage of leaking installations in 2016 was higher for R22 than for HFCs (88%, compared with 43% on average for the whole sample).

No data is available on the amounts leaked. The 2010 report of Milieu-Inspectie had mentioned that it was not possible to estimate the actual leakage rate properly, but that for 28 installations for which that leakage rate was above 5% that year, it reached an average of 110%.

Overall, there has been progress in the reduction of leakage rates, but the fact that the overall quantity of refrigerant delivered to installations in the latest years is only decreasing progressively tends to indicate that the average leakage rate is still significantly higher than the 5% aimed at by the legislation.

At the steering group meeting of 15 October 2010, it has been agreed to make a difference according to the type of refrigerant and keep the leakage rate of R22 plants constant. These plants were to disappear, be retrofitted or be working with HFC drop-in refrigerants, as it is not allowed anymore to place on the market or use HCFCs since 1 January 2015 (Art 11 of EC Regulation 1005/2009).

In the absence of statistical data on the bank or on the emission rate and given the context just described, we have kept our previous assumptions, which we had chosen as simple as possible. For cooling installations including stationary air-conditioning, that was:

- a constant 20% leakage rate for R22 and for the other refrigerants containing at least an HCFC substance (typically ‘drop-ins’, which are used in existing plants);
- for the pure HFC refrigerants, after being constant at a level of 20% up to 1996, the emission rate decreases with a constant percentage to reach 15% in 2003 and continues the same decline afterwards.

For industrial and commercial refrigeration (i.e., after subtracting the chillers for air-conditioning), this translates to a constant level of 22% until 1996, decreasing exponentially to reach 9,5% in 2021.

In the framework of consultations that we held with service companies, operators, refrigerant suppliers, and experts in the field of refrigeration or air-conditioning in 2017, this topic was addressed. Opinions were often diverging, but it could not be concluded that our assumptions would be unrealistic. Besides, although there remains a significant uncertainty on the levels of stocks and emission rates, given the mass balance approach used, the uncertainty on the emissions themselves is lower than that on the stock or the emission rate, as the uncertainties on the bank and on the yearly emission rate tend to compensate each other (see section on the uncertainty analysis).

The calculation of the 'amount in systems at time of disposal' and the percentage recovery are therefore being kept for the time being.

For the penetration of natural refrigerants in new systems, the estimates are multiplied by an 'F-gas fraction', linearly varying from 100% in 2006 to 75% in 2016, and extrapolated to 2021, to take into account the penetration or increased penetration of CO_2 and NH_3 systems. In the absence of aggregate data for Belgium on this topic, this simple assumption is based on data from the French emission inventories for refrigerants [9]. However, given the strong quota reduction of the EU regulation in 2018, the high GWPs of refrigerants R404A and R507A, the strong decline in supply of these refrigerants, of which the price has exploded that year, we have assumed that these two refrigerants are not used in new installations anymore since 2018.

Based on consultations with gas suppliers, it has been assumed that 60% refrigerants R448A and R449B have been used for replacing R404A/R507A in existing installations, the remaining 40% being used in new systems.

It should be noted that, except for the manufacturing emissions, which are marginal, the refrigerant mix in new systems has no impact on current emissions. Because of the mass balance approach of the emission inventory, it is only at the time of disposal, i.e., after 15 years, that the change of refrigerant mix in new systems will take place.

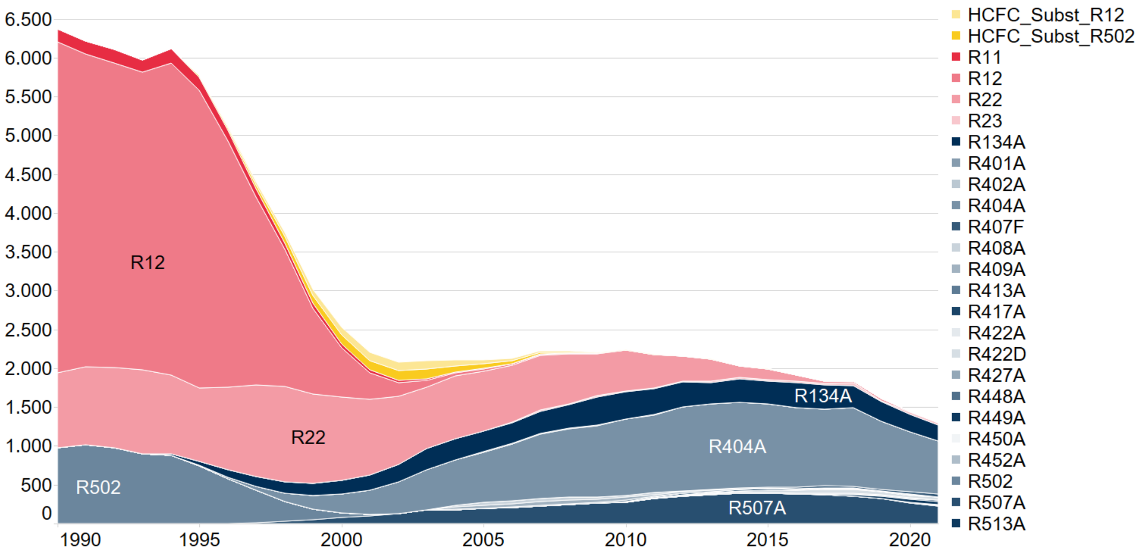
The modelling of the retrofitting of existing installations is based on the supply figures of drop-in refrigerants (R413A, R417A, R422A, R422D, R427A for replacing R22; R407F, R448A and R449A for replacing R404A and R507A). The disposal of the refrigerants replaced takes place earlier than at the end of life, and In the years 2016-2020, disposal emissions of R404A and R507A are higher than if there had been no retrofitting. This implies that the later disposal emissions of these refrigerants will be comparatively lower. Given the mass balance approach, this modelling change does not affect the 'amount in systems at time of disposal' cumulated over time.

In this update 3 more refrigerants have been taken into account: R23 (used for ultra-low temperature cooling, of which the delivery has recently increase in relation with the supply of Covid vaccines), R452A (developed for transport refrigeration, but also for stationary refrigeration, as a replacement for R404A/R507A) and R513A, a low GWP refrigerant used as a replacement for R134a in chillers. The modelling of their emissions is based on their overall consumption. However, there is a lack of data, and hence an uncertainty, on what part of R452A is used on transport refrigeration and what part of R513A is used for air-conditioning. The consumption assumed for Commercial refrigeration (2F1a) is calculated as the balance of deliveries after deducting the consumption for these other sources.

Results

Figure 4-8 shows the total emissions by refrigerant, in terms of CO_2-equivalents. Dominant are R22 in the first place, progressively replaced by R404A, R507A and R134a.

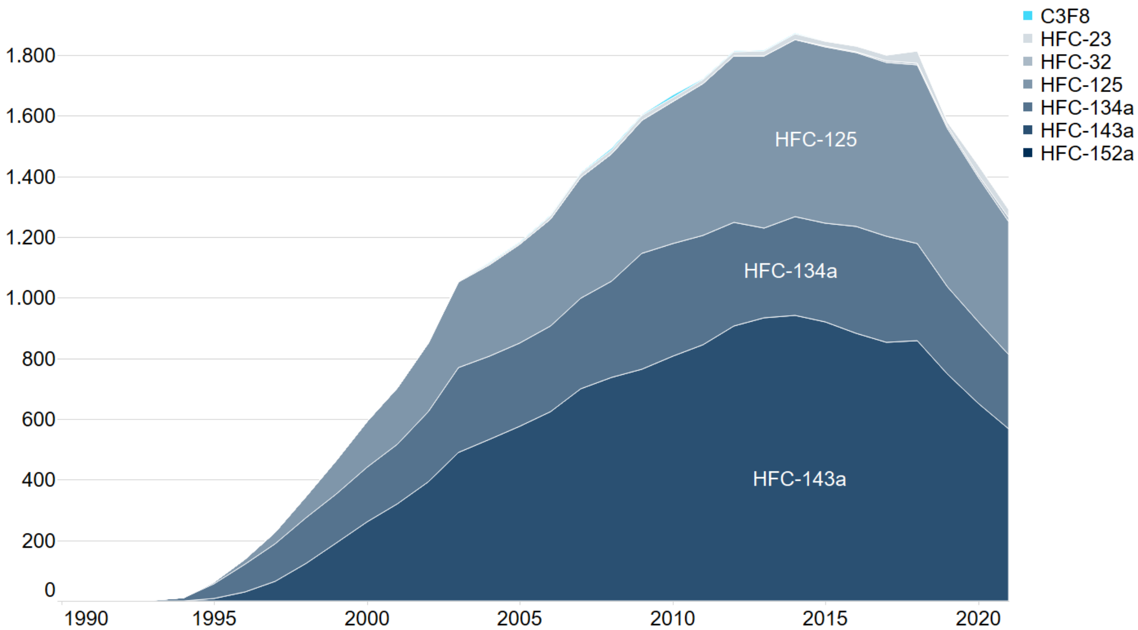
Figure 4-8. Emissions of F-gases from industrial and commercial refrigeration installations by refrigerant (in kt CO_2-eq).



Source: VITO, Econotec (survey, own calculations, 2022).

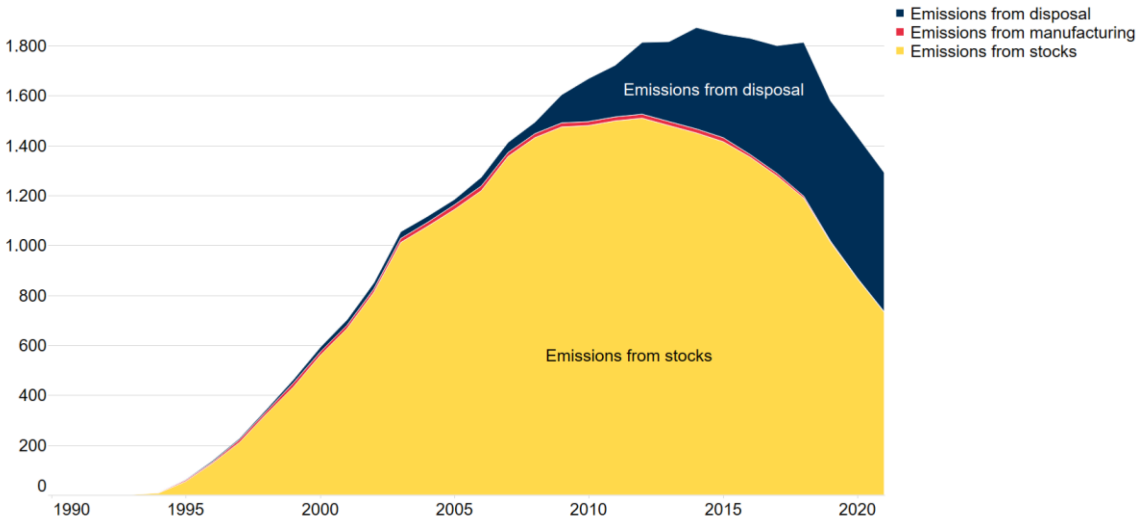
The emissions of CRF F-gases, expressed in CO_2-eq (shown by substance on Figure 4-9 and by type on Figure 4-10), have reached a peak in 2014, but with an increasing share of disposal emissions. It should be recalled that there remains a high uncertainty on the level of the latter emissions. They are assessed from the 'amount in systems at time of disposal' (based on assumed consumptions in new equipment, average equipment lifetime and percentage remaining in systems at time of disposal) and the assumed average recovery rate.

Figure 4-9. Emissions of CRF F-gases from industrial and commercial refrigeration by substance (in kt CO_2-eq).



Source: VITO, Econotec (survey, own calculations, 2022).

Figure 4-10. Emissions of CRF F-gases from commercial and industrial refrigeration by type (in kt CO_2-eq).



Source: VITO, Econotec (survey, own calculations, 2022).

Decreasing emissions from stock are being replaced by increasing emissions from disposal.

Table 4-7. Emissions of F-gases from commercial and industrial refrigeration (kt CO_2-eq).

	1990	1995	2000	2005	2010	2015	2020	2021
ODS	**6.371,8**	**5.699,3**	**1.935,5**	**922,3**	**574,7**	**148,3**	**10,4**	**3,4**
CFC	**5.249,0**	**4.626,0**	**732,5**	**34,6**	**3,2**	**0,5**	**0,1**	**0,1**
CFC-11	167,6	168,0	44,6	7,5	0,7	0,1	0,0	0,0
CFC-12	4.264,1	3.831,1	641,3	27,1	2,5	0,4	0,1	0,1
CFC-115	817,2	626,8	46,6	0,0	0,0	0,0	0,0	0,0
HCFC	**1.122,9**	**1.073,3**	**1.203,0**	**887,8**	**571,5**	**147,8**	**10,3**	**3,3**
HCFC-22	1.122,9	1.073,3	1.178,3	863,6	561,0	146,1	10,0	3,1
HCFC-124	0,0	0,0	10,5	9,2	3,6	0,6	0,1	0,1
HCFC-142b	0,0	0,0	14,2	14,9	7,0	1,1	0,2	0,1
CRF F-gases	**0,0**	**61,1**	**591,1**	**1.183,5**	**1.669,0**	**1.847,3**	**1.436,7**	**1.292,8**
PFC	**0,0**	**0,0**	**0,0**	**2,5**	**7,8**	**0,0**	**0,0**	**0,1**
C3F8	0,0	0,0	0,0	2,5	7,8	0,0	0,0	0,1
HFC	**0,0**	**61,1**	**591,1**	**1.180,9**	**1.661,2**	**1.847,3**	**1.436,7**	**1.292,7**
HFC-23	0,0	0,0	0,0	5,5	13,5	17,9	31,3	28,9
HFC-32	0,0	0,0	0,0	0,0	0,1	1,1	9,4	11,3
HFC-125	0,0	3,9	150,3	325,8	468,9	583,0	475,8	438,4
HFC-134a	0,0	50,4	180,3	274,7	371,8	324,7	269,9	245,8
HFC-143a	0,0	6,9	260,1	574,5	806,9	920,6	650,3	568,3
HFC-152a	0,0	0,0	0,4	0,3	0,1	0,0	0,0	0,0
Other	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Other F-gases	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**
HFO[1]	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**
HFO-1234yf	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
HFO-1234ze	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Total	**6.371,8**	**5.760,4**	**2.526,6**	**2.105,8**	**2.243,7**	**1.995,6**	**1.447,1**	**1.296,2**

Note: [1] values smaller than 0,0

Source: VITO, Econotec (survey, own calculations, 2022).

4.4.2 Domestic refrigeration (2.F.1.b.)

Introduction

This category consists of domestic refrigeration appliances such as refrigerators, freezers (chest or upright), and fridge freezers. Producers of household refrigerators, freezers, and fridge freezers switched from CFC-12 to HFC-134a from 1994. This was however only a small fraction and most started using isobutane as an alternative. As a results only a small share of domestic refrigerators entering the market since 1994 contained HFC-134a. Under the EU F-Gas Regulation [10], imports of household refrigerators and freezers that use refrigerants with GWPs of 150 or higher are prohibited as of 2015.

Methodology

Domestic refrigerators are divided into three categories: independent refrigerators, independent freezers, and refrigerator/freezers.

The number of new household refrigerators and freezers is calculated based on the stock of equipment and the estimated number of end-of-life refrigerators. No sale statistics for Belgium are readily available. Of the new refrigerators and freezers, it is assumed that none use HFC-134a as cooling agent and HFC-245fa in foam from 2015. For the period 1999-2010, the Household Budget Survey provides data on the number of refrigerators and freezers per household for Flanders, Wallonia, and Brussels. The survey has changed from an annual to a bi-annual one. However, because the quality of the information is not similar to the previous survey[6], we do not use the household budget enquiry but assume a linear extrapolation of the percentage ownership between 2010 and 2014 for all three types of equipment. To calculate the number of refrigerators and freezers, the percentage ownership is multiplied with the number of households. The number of households in Flanders, Wallonia, and Brussels for 2010 - 2016 was completed with information from the Federal Planning Bureau. Because no new equipment containing HFCs is placed on the market from 2015, assumptions relating to the stock of equipment is not relevant anymore in the calculation of the emissions.

Manufacturing emissions are set to zero.

The annual emission factor for standing domestic refrigerators and freezers is 1% (HFC-134a) and 0,25% (HFC-245fa), irrespective of the type (refrigerator, freezer, and combination) (see IPCC methodology below).

Equation: Emissions during equipment lifetime

$$E_{lifetime,t} = B_t \times \frac{x}{100}$$

$E_{lifetime,t}$ = amount of HFC emitted during system operation in year t, kg

B_t = amount of HFC banked in existing systems in year t (per application), kg

x = annual emission rate (i. e. emission factor) of HFC of each application bank during operation accounting for average annual leakage and average annual emisions during servicing, percent

Domestic refrigerators and freezers have an average lifetime of 15 years, this is the same as in Germany, the Netherlands or the UK. The number of refrigerators that are end of life in 2021 is the same as the number of new refrigerators in year x-15. This is an assumption; in reality discarded refrigerators will have different ages. Statistics on the number of refrigerators and freezers collected in Flanders, Brussels and Wallonia are published by Recupel (not publicly available). The Recupel reports also contain information on the amount of HCFC, CFC, HFC and HC recovered. This is the amount recovered from equipment collected in each region, but not necessarily dismantled in that region (see below). The information however does not distinguish between the different types of substances and therefore cannot be used. CoolREC (personel

6 The household budget enquiry collected data only for refrigerators in 2013 (and not for independent freezers or combination refrigerator/freezers). The 2013 enquiry shows that the ownership of a refrigerator by households has gone up considerably in all three regions (for Wallonia and Brussels more than 44 percentage points). It is assumed that with the new questionnaire respondents also counted refrigerator/freezers.

communication, 2021) confirmed that CFC-containing refrigerators and freezers are still being collected and dismantled.

Emissions from disposal (see IPCC methodology below) can occur at two different stages of the process: 1) on site, during collection, storage and transport from the collector to the dismantling plant; and 2) at the dismantling plant. The emission factor for the first type of emissions is assumed to be 30% and the emissions occur in the region where refrigerators and freezers originate from. Recent information from Recupel showed that around 30% of domestic refrigerators are not dismantled correctly[7].

Equation: Emissions at end of life

$$E_{end\ of\ life,t} = M_{t-d} \times \frac{p}{100} \times \left(1 - \frac{\eta_{rec.d}}{100}\right)$$

$E_{end\ of\ life,t}$ = amount of HFC emitted at time of disposal in year t, kg

M_{t-d} = amount of HFC initially charged into new systems installed in year (t − d), kg

d = lifetime

p = residual charge of HFC in equipment being disposed of expressed in percentage of full charge, %

$\eta_{rec,d}$
= recovery efficiency at disposal, which is the ratio of recovered HFC to the HFC contained in the system, %

Dismantling of refrigerators and freezers does not take place in each region. From 2012, all refrigerators and freezers collected in Flanders are exported for dismantling to either Germany, the Netherlands or Wallonia (only exports for dismantling outside Belgium are considered). All refrigerators and freezers collected in Wallonia and Brussels are assumed to be processed in Wallonia (by Recydel). Recupel provided information on the recovery efficiency which, according to the WEEE forum standard, should be at least 90% (pers. comm. 2014). The recovery efficiency was therefore considered to be 90% for all HFCs in 2020, which is a conservative estimate.

Table 4-8. Assumptions for domestic refrigerators and comparison with IPCC 2006 guidelines.

	HFC-134a	HFC-245fa	IPCC 2006	2019 refinement
Charge (kg)	0.1	0.325	0.05 < M < 0.5	0.05 < M < 0.5
Lifetime (yr)	15	15	12 < d < 20	12 < d < 20
Manufacturing EF (%)	NA	NA	0.2% < EF < 1%	0.2% < EF < 1%
Operational EF (%)	1%[1]	0,25%	0,1% < EF < 0,5%	0,1% < EF < 0,5%
Recovery efficiency (%)	63%[2]	90%	0% < RE < 70%	0% < RE < 70%

Note: [1] Previous IPCC guidelines proposed 1% emission factor, which was kept constant to have consistent time series (impact is limited). [2] Assuming that 30% of HFC-134a is emitted before dismantling and 90% is recovered at dismantling site (based on information of Récydel).

7 Meer dan 200.000 koelkasten en diepvriezers vermist: incorrecte recyclage zorgt voor enorme milieuschade (prezly.com)

Table 4-9. Comparison of assumptions for domestic refrigerators between selected countries.

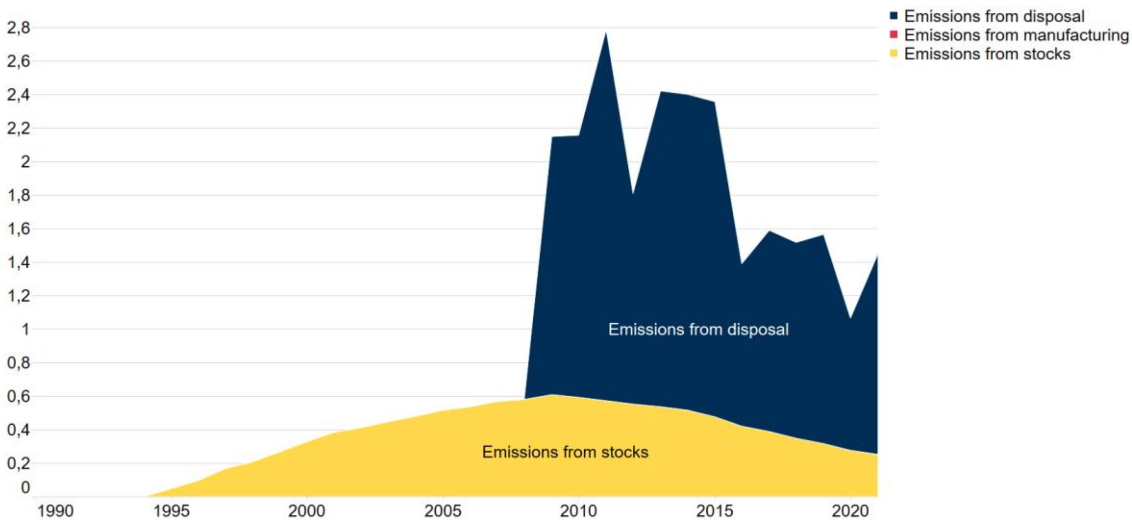
Assumption	Belgium	France	Germany	UK
Charge (g)	100	56 - 73	NR	30 - 100
Share R134a (%)	0%	0%	0%	0%
Lifetime (yr)	15	15	15	15
Manufacturing EF (%)	NO	0,2%	NO	1%
Operational EF (%)	1%	0,01%	0,30%	0,1%
Disposal EF (%)	37%	44%	27%	58%

Source: Information taken from NIR (HTTPS://UNFCCC.INT/GHG-INVENTORIES-ANNEX-I-PARTIES/2022).

Results

As the use of refrigerants is prohibited in domestic refrigeration, emissions are decreasing as more and more refrigerators and freezers containing HFCs are replaced by equipment without HFCs. Since 2009, disposal emissions are important. The sudden increase is because of simplified assumptions relating to the lifetime of refrigerators and freezers. Disposal emissions are relevant as a substantial amount of equipment is not dismantled correctly, resulting in relatively high emission rates compared to emissions during operation. The annual fluctuations are also a result of fluctuating disposal emission.

Figure 4-11. Emissions of CRF F-gases from domestic refrigerators in Belgium (in kt CO_2-eq).



Source: VITO, Econotec (own calculations, 2022).

4.4.3 Industrial refrigeration (2.F.1.c.)

Is included under commercial refrigeration (2.F.1.a).

4.4.4 Transport refrigeration (2.F.1.d.)

Introduction

HFCs have been used as refrigerants in refrigerated vehicles since 1993. Today, HFC-134a, along with the refrigerant mixtures R404A and R410A, are most commonly used. Since 2015, R452A has also been in increased use [11].

Refrigerated containers (reefers) are used primarily for transports by ocean-going ships. Therefore emissions take place in international waters or when reefers are placed on shore. Considering In Germany emissions are calculated on global scale and subsequently Germany's share in the global economy is used to allocate emissions to Germany. Since 1993, the most commonly used refrigerant has been HFC-134a. Since 1997, R404A has also been used. In recent years, the refrigerant blends R452A and R513A have also been introduced [12].

Methodology

Data on the fleet and new registrations of refrigerated trucks and trailers for 2021 were obtained from the FPS Mobility for different weight categories (i.e. 2 - 5 ton, 5 - 9 ton, 9 - 22 ton, > 22 ton).

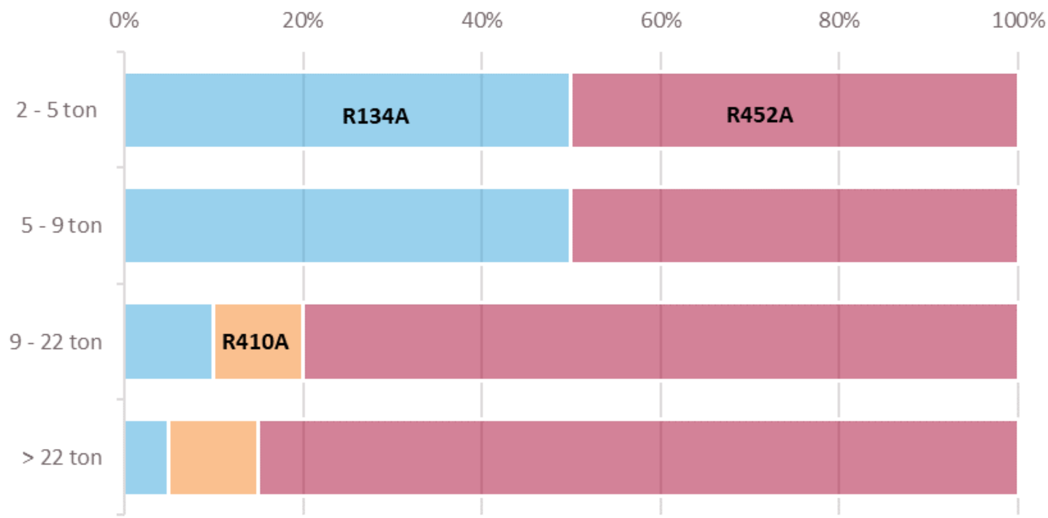
Manufacturing does not occur in Belgium and therefore manufacturing emissions are zero. However, filling of empty systems does occur. Emissions are included in the annual operational emissions.

The data shows that in the period 2009-2013 and again since 2018 few new refrigerated trucks were registered. Based on a personal communication with the FPS Mobility, data for these years were adjusted based on the percentage of newly registered trucks where this information (refrigerated/non-refrigerated) was not recorded (in the period 2009-2013) or based on a minimum fixed share of refrigerated trucks from all trucks newly registered (1,5% in the period 2018-2021). In 2014-2017 the statistics were considered reliable.

The stock of refrigerated trucks is modelled based on the number of new registered trucks (starting in 1993) and assuming an average lifetime of 12 years. Information on the substances and average quantities of fluorinated greenhouse gases in each weight category is based on assumptions taken from Schwarz [13] and personal communication. Based on this and the German NIR [11], assumptions have been adjusted.

R452A is one of the replacements for high-GWP refrigerants and it is assumed that most new refrigerated transport is equipped with R452A. The use of R452A started in 2017. This corresponds with the supply of R452A on the Belgian market, which started in 2016. The quantities placed on the market however increased rapidly to 28,6 t in 2021. This far exceeds the quantities needed to refill refrigerated transport. It was estimated that in 2021 only 0,6 t of R452A would be needed. R452A is a replacement for R404A, so might be used in other applications as well. Quantities of R404A placed on the market in Belgium also far exceed quantities needed to service refrigerated transport.

Figure 4-12. Share of refrigerants in different weight categories of new refrigerated transport in Belgium (%).



Operational emissions are calculated with an emission factor of 15% for both new and retrofitted systems.

The disposal emission factor is 30% for all gases and all weight classes.

As far as maritime transport is concerned, the emissions of reefers serviced in Belgium are not known, but the reefer service companies operating in the country seem to mostly purchase their refrigerants (directly or indirectly) from companies participating in our survey on the supply of refrigerants. Therefore, the emissions from reefers are probably to a large extent included in those calculated for the industrial and commercial 'installations'. The situation should be similar for the maintenance of ships.

Table 4-10. Comparison of assumptions for refrigerated transport between selected countries.

	Belgium	France	Germany	UK
Lifetime (yr)	**12**	**NA**	**10**	**9 - 15**
Charge (kg)	**1,5 – 9**	**2 – 6,6**	**Not reported**	**1 - 10**
Manufacturing EF (%)	**NA**	**1%**	**5 gr**	**2%**
Operation EF (%)	**10%**	**12 – 18%**	**15 – 30%**	**23%**
Disposal EF (%)	**30%**	**30%**	**34,3%**	**60%**

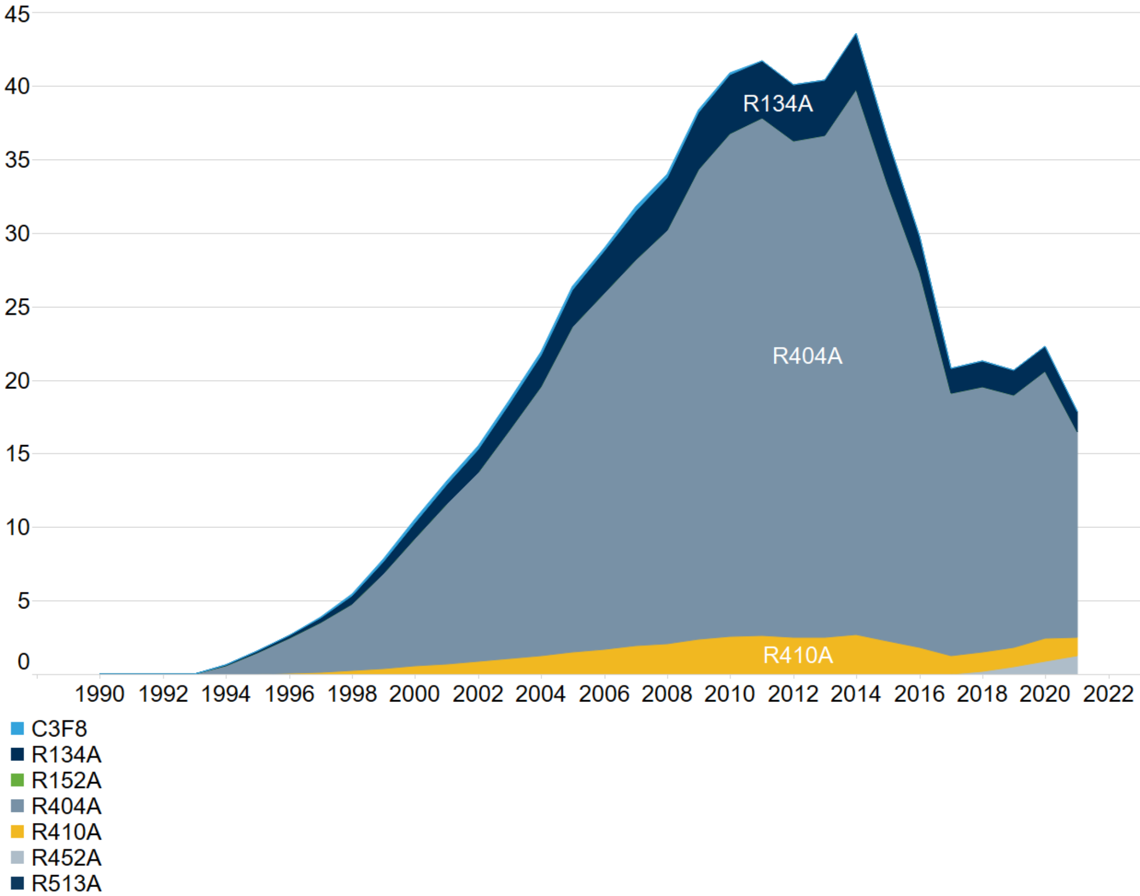
Source: Information taken from NIR (HTTPS://UNFCCC.INT/GHG-INVENTORIES-ANNEX-I-PARTIES/2022).

Results

The emissions from refrigerated transport are dominated by three refrigerants: R404A, R410A and HFC-134a. In more recent years, these refrigerants have been replaced by R452A, which has a much lower GWP-value. Emissions are apparent from 2018 onwards.

R452A is a refrigerant mostly used for transport refrigeration, vans, trucks, or reefers. It can be used as a replacement of R404A. Since its use it has replaced R404A completely.

Figure 4-13. Emissions of F-gases from refrigerated transport in Belgium (in kt CO_2-eq).



Source: VITO, Econotec (own calculations, 2022).

Table 4-11. Emissions of F-gases from transport refrigeration (kton CO_2-eq.).

	1990	1995	2000	2005	2010	2015	2020	2021
CRF F-gases	**0,0**	**1,5**	**10,5**	**26,3**	**40,9**	**36,4**	**22,3**	**17,9**
PFC	**0,0**	**0,0**	**0,2**	**0,2**	**0,1**	**0,0**	**0,0**	**0,0**
C3F8	0,0	0,0	0,2	0,2	0,1	0,0	0,0	0,0
HFC	**0,0**	**1,5**	**10,3**	**26,1**	**40,8**	**36,4**	**22,3**	**17,9**
HFC-32	0,0	0,0	0,1	0,3	0,5	0,4	0,3	0,3
HFC-125	0,0	0,5	3,5	9,0	14,2	12,8	8,6	7,2
HFC-134a	0,0	0,1	1,2	2,8	4,5	3,5	1,9	1,6
HFC-143a	0,0	0,9	5,5	14,0	21,6	19,7	11,5	8,8
HFC-152a	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Other F-gases	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**
HFO	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**
HFO-1234yf	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Total	**0,0**	**1,5**	**10,5**	**26,3**	**40,9**	**36,4**	**22,3**	**17,9**

Source: VITO, Econotec (own calculations, 2022).

4.4.5 Mobile air-conditioning (2.F.1.e.)

Introduction

The mobile air-conditioning systems category includes air-conditioning systems in cars, trucks and utility vehicles, buses and coaches, and railway vehicles. HFCs have been used in mobile air-conditioning systems since 1991. The share of vehicles equipped with air-conditioning has seen an important growth over the years. HFC-134a was by far the most commonly used refrigerant. Due to the Mobile Air-conditioning Directive [14], HFO-1234yf is increasingly being used in automobile air-conditioning systems since 2012.

Methodology

- **Cars**

A questionnaire has been sent to all car manufacturers in Belgium asking for their consumption of HFC-134a and HFO-1234yf in 2020 and their emissions.

Data on the total number of cars produced in Belgium over the past year were obtained from FEBIAC and the number of new cars registered in Belgium from the national statistics office.

To calculate the emissions from car air-conditioning systems, the share of new cars equipped with air-conditioning systems must be known. For 2021 the share is estimated to be 96%. This is assumed to be the maximum saturation level, based on Schwartz [15]. We have assumed that in Belgium this value was reached in 2010. In Belgium, no systematic registration of the fact that new cars are equipped with air-conditioning is currently performed.

Up to 2012 we have assumed that all cars on the Belgian market with air-conditioning are equipped with HFC-134a. From 1 January 2013, the temporary exemption of HFO-

1234yf in car air-conditioning has been lifted [8]. Few data exist on the use of HFO-1234yf in cars in Europe at the moment. In Germany, only 458.532 cars have been registered between January 2013 and June 2015 that are equipped with HFO-1234yf, which corresponds to approximately 1% of the total car fleet or 6,2% of cars sold [16]. In Belgium, we assume that 1,4% of cars sold in 2013 contain HFO-1234yf[9], 6% in 2014, 24% in 2015, 82% in 2016 and 100% in 2017 taking into account a gradual increase in number of cars.

It is assumed that CO_2 has not been used in car mobile air-conditioning systems. This is an assumption, but as the GWP values are the same, there is no impact on the emissions expressed in CO_2-eq.

An important assumption is the amount of HFC-134a or HFO-1234yf in the air-conditioning system of new cars. We have used the data from Schwartz [13], which are for the years up to 2002, and had kept for the later years the unitary load of 0,7 kg given for 2002. However, the mean weight of HFC-134a in the air-conditioning of cars manufactured in Belgium is now significantly lower, ranging between 0,5 and 0,6 kg. If we look at the data from Öko-Recherche with the average amount of HFC-134a for the period 1992 until 2003, we can see a clear linear decrease. We extrapolated this linear trend, which gives 0,5 kg in 2010 and the years thereafter. This seems to correspond with the information provided by some Belgian car manufacturers (combining both large and small models).

A significant problem with the emission inventory for cars is that we use a model to determine the number of vehicles with air-conditioning and the bank of coolants in these vehicles. Statistics from FEBIAC and the national statistics office, and assumptions on the percentage new vehicles with air-conditioning are used as input variables. These statistics are reliable, and the assumptions are supported by reports and scientific studies from neighbouring countries. However, when considering vehicles that are end-of-life, there is a significant difference between the model outcome and available statistics published by Febelauto. Febelauto confirmed that the published statistics are not a complete representation of the number of cars that have been disposed of in Belgium. There are two explanations. First, not all vehicles are dismantled in official centres. This only explains part of the difference, Febelauto estimates that 30% of cars are dismantled illegally. Second, some cars that are end-of-life or near end-of-life are exported (to be dismantled or used). This could be up to 56%, according to Febelauto (personal communication, 2014). That corresponds with our estimation of the number of cars that have reached end-of-life.

Therefore, we adjusted the calculation methodology from 2013 to align the model output regarding end-of-life cars and the statistics from Febelauto. The number of dismantled vehicles reported by Febelauto is increased with 30% (to account for cars illegally dismantled in Belgium). We assume that all HFC-134a contained in these vehicles will be emitted, except for the quantity recovered in dismantling centres (2,58 t in 2014, of which 90% originates from cars, as published by Febelauto). The remaining cars that according to the model are expected to be end-of-lifetime are assumed to be exported to either EU or non-EU countries. For 2021, this is 75%. Previously, the percentage was

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8 Declaration by the European Commission regarding Point 9. of the agenda of the 31st meeting of the ‘Technical Committee - Motor vehicles’ (TCMV): State of Play of the EU Mobile Air-Conditioning directive (2006/40/EC). Brussels, 19th December 2012

9 This was calculated based on the sales statistics in 2013 for car manufacturers and assuming that manufacturers that already have models equipped with HFO-1234yf, 10% of the models sold contain HFO-1234yf and not HFC-134a.

an assumption, based on personal communication with Febelauto. With this approach model outcome and statistics from Febelauto are aligned. The underlying assumption is that the characteristics of cars that are dismantled in Belgium and cars that are exported are the same. This is not necessarily the case and cars dismantled in Belgium are relatively older and/or equipped less with air-conditioning than average (Febelauto, pers. comm. 2016).

The emission factor for cars during lifetime is estimated to be 8,8%, including regular and irregular losses. This is in line with assumptions from other neighbouring countries. In addition, the model assumed that cars are refilled twice over their lifetime, with emissions occurring at that point in time. This approach is likely an overestimation and is not consistent with the quantities placed on the market. The approach was therefore adjusted with smaller emissions (2%).

- **Buses and coaches**

Information on consumption and emissions of HFC-134a was received from all Belgian manufacturers. Consumption of HFC-134a is decreasing, because of the shift to R407C (in electric buses) and purchases of prefilled air-conditioning systems.

The number of new registrations of buses and coaches was taken from the national statistics office.

The data is split between public buses, other buses and coaches because of differences in the percentage of vehicles with air-conditioning and differences in the load of refrigerant. We assume that 100% of coaches and, since 2019 100% of buses are equipped with air-conditioning. The percentage buses with air-conditioning was previously calculated based on information from De Lijn, TEC and MIVB. However, also other companies might operate buses. This averages to an assumption of 50%, also used previously, which was supported by Van Hool (personal communication, 2014) as a reasonable assumption.

We use a model approach to estimate the number of buses and coaches with air-conditioning in the entire fleet. In 2021, 49% of buses and coaches had air-conditioning. The total fleet of buses and coaches for 2021 was obtained from the national statistics office. Operational emissions are calculated assuming an emission factor of 15%. It is expected that the quantities emitted annually are compensated by an equivalent recharge in the same year. This is different from the model for cars.

An average lifetime of 17 years is assumed. The disposal emission factor is 30%. This is relatively low, compared to cars, but there are no statistics on recovery of HFC-134a from buses and coaches or trucks and therefore we use the assumption used in the German emission inventory.

- **Trucks**

Information on refrigerant use and emissions of manufacturing was obtained from the only Belgian manufacturer. There can be a substantial difference between the theoretical emissions resulting from filling the air-conditioning system, estimated at 0,2%, and the difference between the quantity filled and the quantity consumed (10% in 2020 and 1,2% in 2021 for HFC-134a). For the inventory, we used an emission factor of 1%. The Belgian truck manufacturer is making the transition to HFO-1234yf. While HFC-134a was still used in 2021, quantities were already lower than for HFO-1234yf.

The number of newly registered trucks was obtained from the FPS Economy. It was allocated to three different weight categories (assumptions taken from Schwartz [13]). For each weight category, different assumptions are taken with respect to percentages of new vehicles equipped with air-conditioning.

Operation emission factors are taken from Schwartz [17], who estimated this at 8,3% for vans (< 1,5 t) and 11,2% for larger trucks (=< 1,5 t). These emitted quantities are recharged annually.

The total truck fleet in Belgium and the number of trucks with air-conditioning (for each weight category) are calculated based on a model.

The European MAC directive applies to both cars and vans (M1 and N1). It is assumed that the share of vans equipped with HFO-1234yf is similar to that of passenger cars (100% HFO-1234yf from 2018 onwards). For other trucks (=< 1,5 t) the share is assumed to be zero, although some manufacturers are using HFO in their new models.

To assess the number of trucks disposed of, an average lifetime of 12 years is assumed. The percentage of trucks with air-conditioning is increasing, but at a relatively slow rate because not all new trucks are assumed to be equipped with air-conditioning (especially vans and smaller trucks).

It is assumed that 70% of the quantities of HFC-134a contained in disposed trucks are recovered and 30% is emitted.

- **Rail**

Trams and metros with air-conditioning are excluded in this assessment. An important part of the trains do have air-conditioning. Information of the NMBS/SNCB was requested on the number of trains with air-conditioning in 2021 and the consumption of refrigerants for servicing trains.

The average quantity of HFC-134a per vehicle, by type, is used from the NMBS/SNCB. For the HST this was 5, 15 and 30 kg of R407C for respectively the motor wagons, trains and restaurant carriages. For emissions during lifetime, the emission factor is calculated based on quantities consumed by the NMBS/SNCB for servicing the air-conditioning systems (data from the NMBS/SNCB).

The disposal emissions are estimated at 15%, but it is expected that the first trains with air-conditioning will be taken out of service only in 2024.

- **Other vehicles**

Other vehicles include agricultural vehicles (tractors) and special vehicles (vehicles with a dimension and weight exceeding the established maximum limits, 44 tonnes), can also be equipped with air-conditioning. Emissions from these vehicles was estimated based on:

- the number of new registrations taken from https://statbel.fgov.be/;
- average lifetime (30 years);
- share of vehicles equipped with air-conditioning (95%);
- and assumptions on the quantity and refrigerants used (1,14 kg of HFC-134a).

Assessments of emissions were done in the past, but these were not included in the inventory. The methodology and assumptions seem sound and therefore have now been included under the 2.F.1.e. category in the emission inventory.

Table 4-12. Comparison of assumptions for manufacturing emissions between selected countries.

	Belgium	France	Germany	UK
cars	**1 – 4,3%**	**0,23%**	**3 gr**	**1%**
buses and coaches	**2,4%**	**0,13%**	**50 gr**	**2%**
trucks	**1 – 1,9%**	**0,23%**	**5 gr**	**2%**
rail	**NA**	**1,5%**	**0,5 %**	**2%**
tractors	**NA**	**0,23%**	**5 gr**	**2%**
other vehicles	**NA**	**0,23%**	**5 gr**	**2%**

SOURCE: INFORMATION TAKEN FROM NIR (https://unfccc.int/ghg-inventories-annex-i-parties/2022).

Table 4-13. Comparison of assumptions for operation emissions between selected countries.

	Belgium	France	Germany	UK
cars	**8,8%**	**8%**	**10%**	**5%**
buses and coaches	**15%**	**10%**	**15%**	**15%**
trucks	**8 – 11%**	**8%**	**15%**	**15%**
rail	**5,2 – 7,4%**	**5%**	**6%**	**15%**
tractors	**15%**	**8%**	**15%**	**15%**
other vehicles	**15%**	**8%**	**25%**	**15%**

SOURCE: INFORMATION TAKEN FROM NIR (https://unfccc.int/ghg-inventories-annex-i-parties/2022).

Table 4-14. Comparison of assumptions for disposal emissions between selected countries.

	Belgium	France	Germany	UK
cars	**21%**	**46%**	**50%**	**65%**
buses and coaches	**30%**	**12%**	**38%**	**65%**
trucks	**30%**	**92%**	**50%**	**65%**
rail	**10%**	**92%**	**80%**	**65%**
tractors	**30%**	**92%**	**11,7%**	**65%**
other vehicles	**30%**	**92%**	**11,7%**	**65%**

SOURCE: INFORMATION TAKEN FROM NIR (https://unfccc.int/ghg-inventories-annex-i-parties/2022).

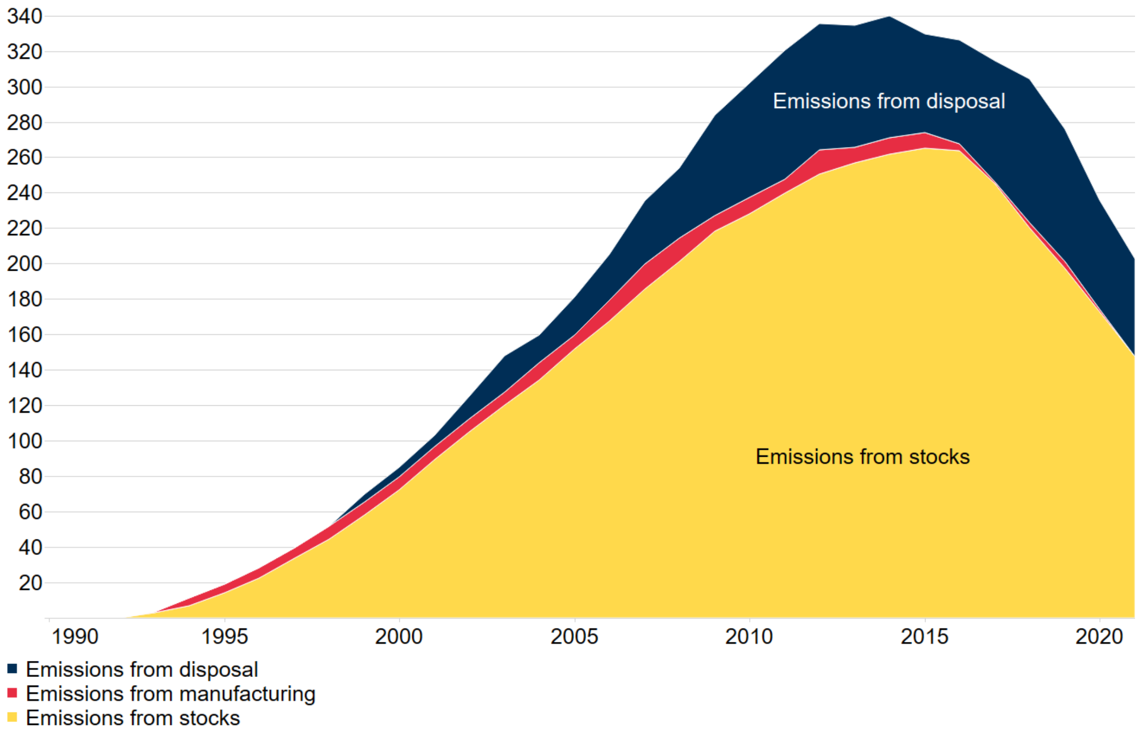
Results

- **Cars**

After the implementation of the MAC Directive, total emissions from car air-conditioning peaked in 2014 and decreased rather sharply after. Lifetime emissions followed a similar trend, peaking in 2015 and 2016 and sharply declining after, while manufacturing and disposal emissions follow entirely different trends. Disposal emissions hovered around

50 t from 2010 to 2014, peaked in 2018 and have been decreasing since. In 2021, disposal emissions were estimated to be 43 t of HFC-134a. While there is still consumption of HFC-134a at car manufacturers, the emissions have dropped from 320 t in 2014 to just 2 t in 2021.

Figure 4-14. Emissions of CRF F-gases from car air-conditioning in Belgium (in kt CO_2-eq).

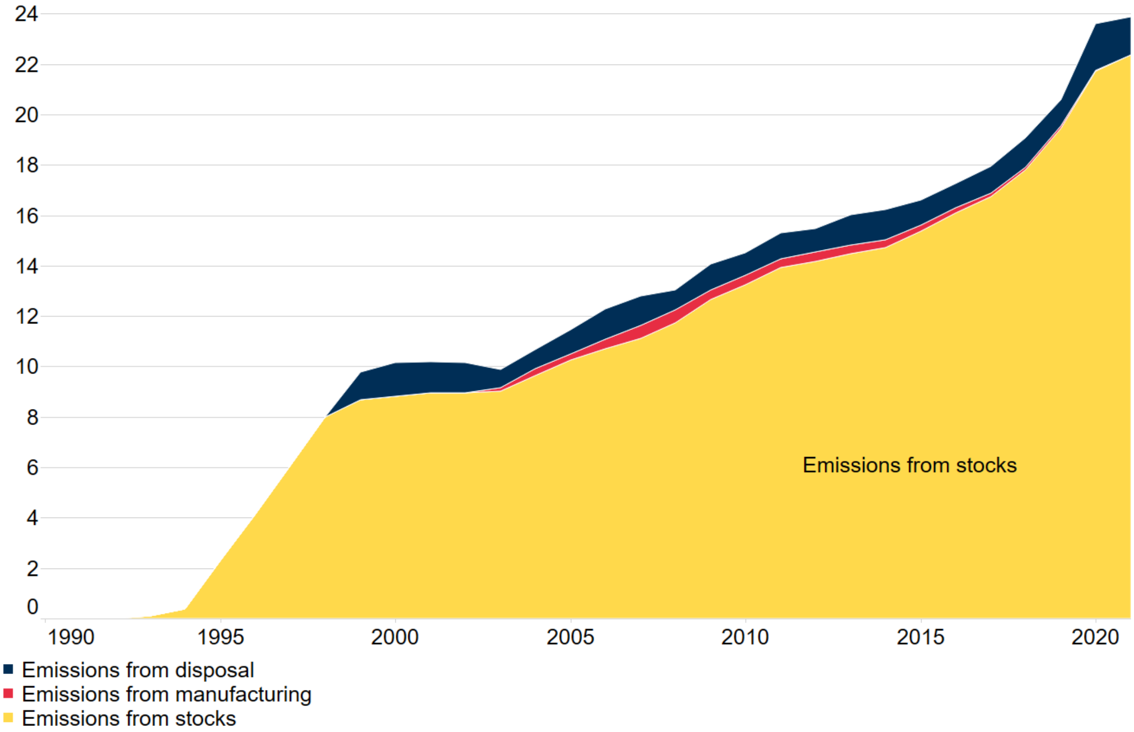


SOURCE: VITO, ECONOTEC (OWN CALCULATIONS, 2022).

➢ Buses and coaches

HFC Emissions in buses and coaches are still increasing, mostly because the stock of buses and coaches equipped with an air-conditioning system is increasing, resulting in increased emissions during use. The emissions are however small compared to emissions from cars.

Figure 4-15. Emissions of CRF F-gases from bus and coach air-conditioning in Belgium (in kt CO_2-eq).

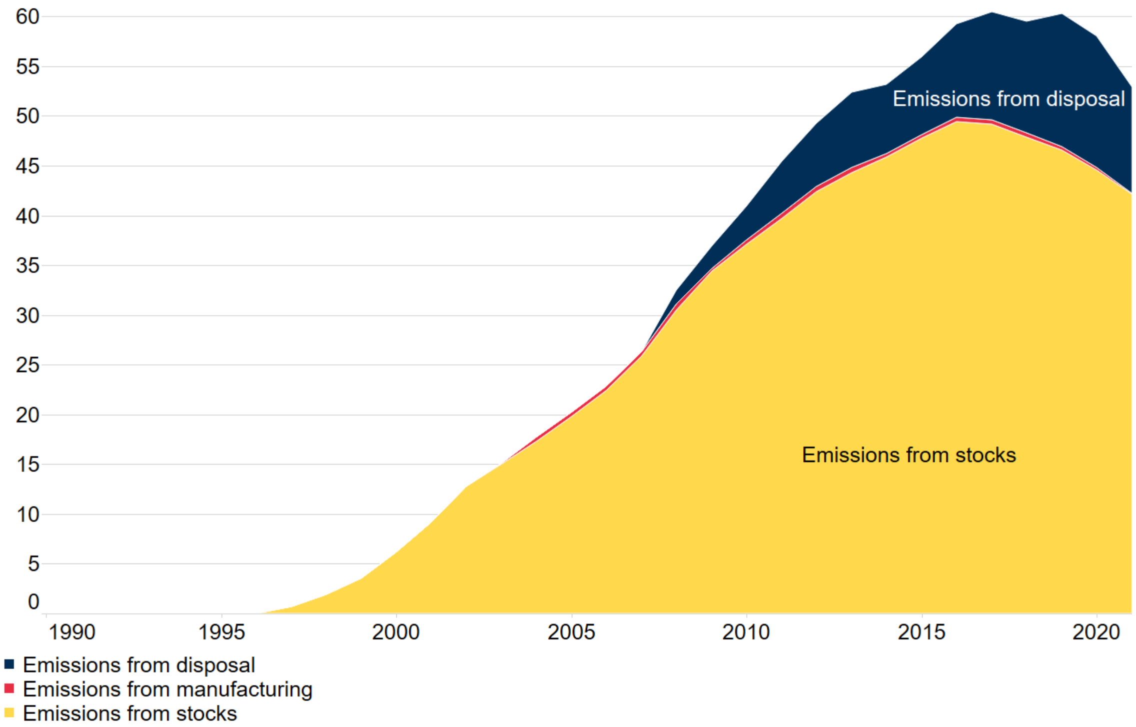


SOURCE: VITO, ECONOTEC (OWN CALCULATIONS, 2022).

➢ Trucks

In trucks, HFC emissions are decreasing. This is caused primarily by the use of HFO-1234yf in small commercial vehicles. It illustrates the potential effect a shift to HFO - 1234yf in other commercial vehicles could have, as now implemented by Volvo. Emissions from disposal are still increasing, as more and more trucks with air-conditioning are end of life.

Figure 4-16. Emissions of CRF F-gases from truck air-conditioning in Belgium (in kt CO_2-eq).

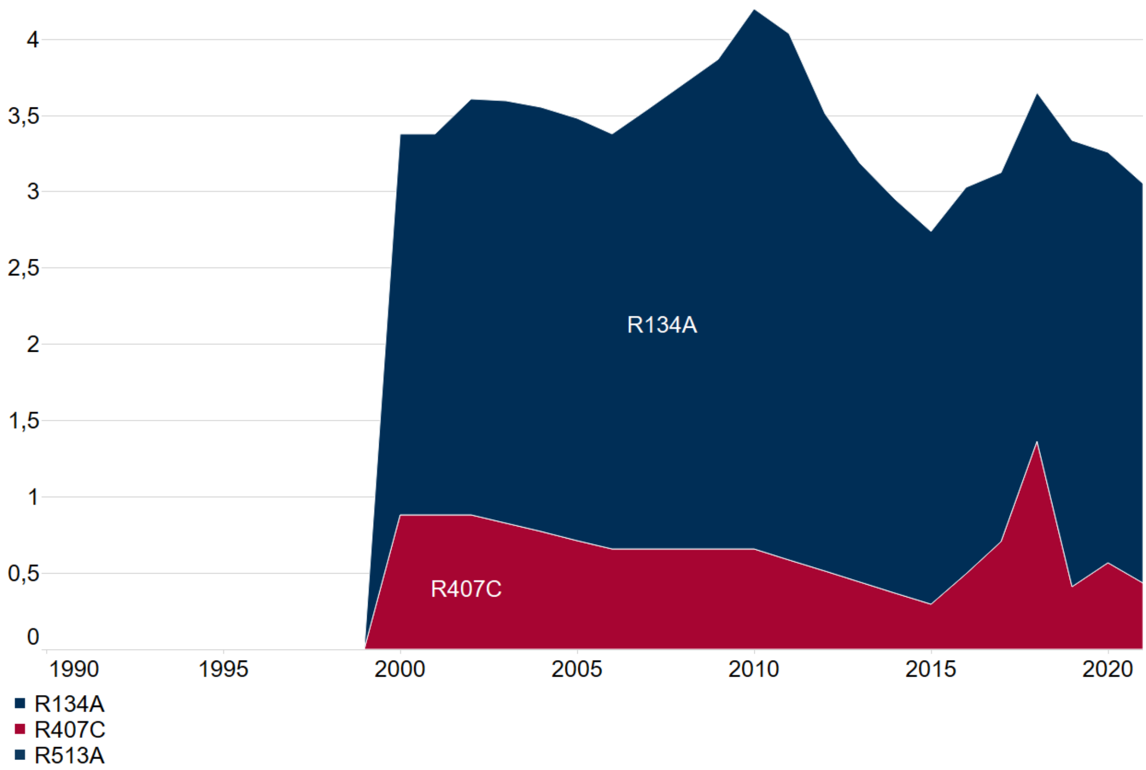


Source: VITO, Econotec (own calculations, 2022).

➢ Rail

Emissions from rail are stable. The stock of equipment with air-conditioning is not increasing and therefore emissions are relatively constant.

Figure 4-17. Emissions of F-gases from rail air-conditioning in Belgium (in kt CO_2-eq).

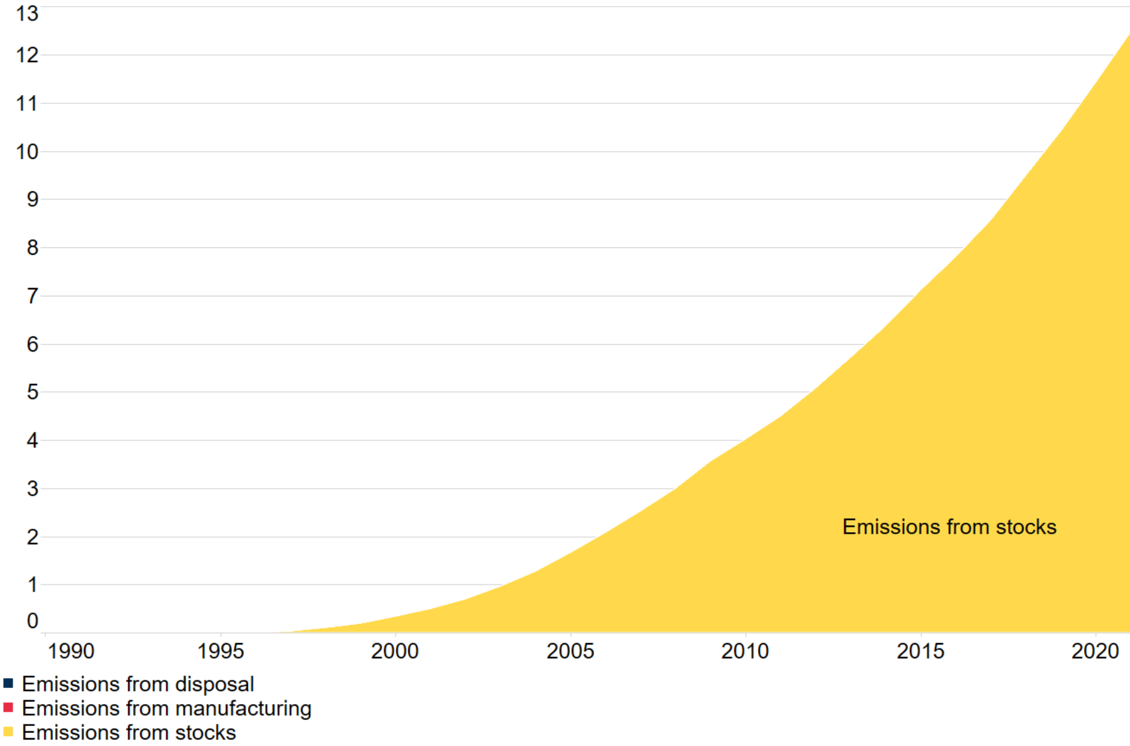


Source: VITO, Econotec (ow calculations, 2022).

➢ Other vehicles

Other vehicles include agricultural vehicles and special vehicles. Emissions are increasing, due to the increasing bank of HFC-134a in these vehicles. The emission factor is kept constant across all years.

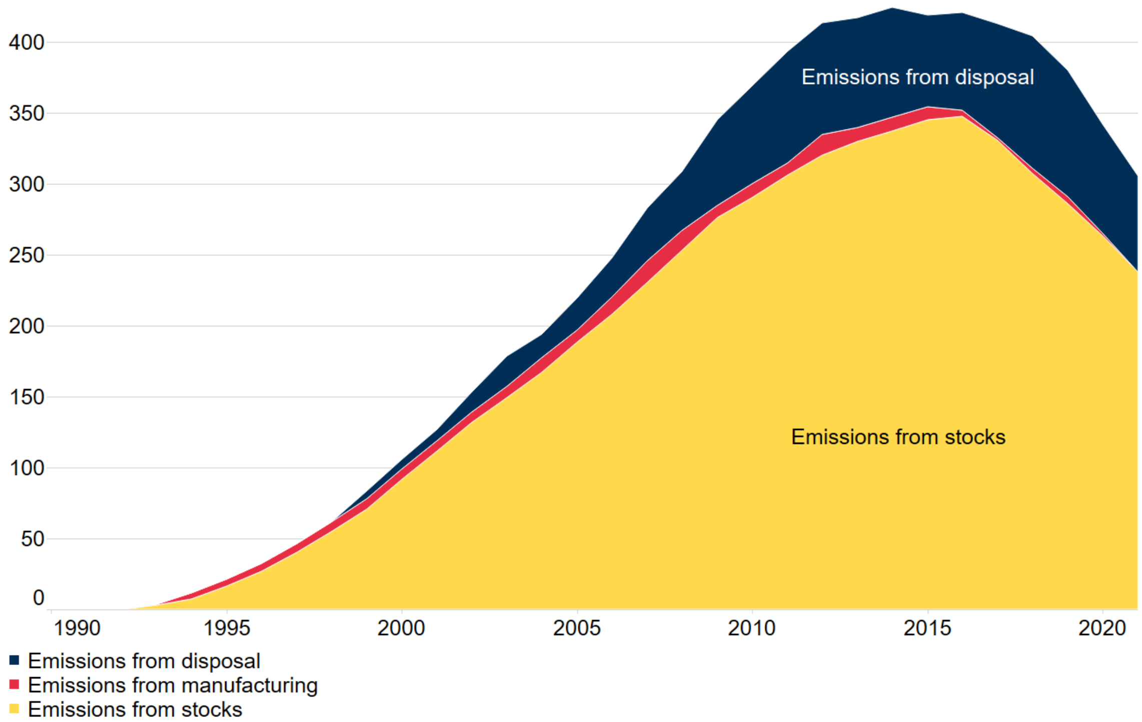
Figure 4-18. Emissions of CRF F-gases from other vehicles air-conditioning in Belgium (in kt CO_2-eq).



Source: VITO, Econotec (ow calculations, 2022).

- **Total emissions**

Figure 4-19. Emissions of CRF F-gases from mobile air-conditioning in Belgium (in t).



Source: VITO, Econotec (ow calculations, 2022)

Table 4-15. Emissions of F-gases from mobile air-conditioning (kton CO_2-eq.).

	1990	1995	2000	2005	2010	2015	2020	2021
ODS	**114,4**	**183,8**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**
CFC	**114,4**	**183,8**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**
CFC-12	114,4	183,8	0,0	0,0	0,0	0,0	0,0	0,0
CRF F-gases	**0,0**	**21,4**	**105,2**	**219,5**	**368,7**	**418,8**	**341,9**	**305,3**
HFC	**0,0**	**21,4**	**105,2**	**219,5**	**368,7**	**418,8**	**341,9**	**305,3**
HFC-32	0,0	0,0	0,1	0,1	0,1	0,0	0,2	0,3
HFC-125	0,0	0,0	0,4	0,3	0,3	0,1	1,1	1,4
HFC-134a	0,0	21,4	104,7	219,1	368,3	418,6	340,6	303,7
Other F-gases	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,1**	**0,1**
HFO	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,1**	**0,1**
HFO-1234yf	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,1
Total	**114,4**	**205,2**	**105,2**	**219,5**	**368,7**	**418,8**	**342,0**	**305,4**

Source: VITO, Econotec (ow calculations, 2022)

4.4.6 Stationary air-conditioning (2.F.1.f.)

Introduction

This source category comprises plug-in movable air-conditioners, room air-conditioners (RAC), heat pumps, chillers, heat pump boilers and heat pump dryers.

Methodology

Data were received from the only manufacturer of air-conditioning and heat pumps in Belgium on refrigerant use and emissions during manufacturing of heat pumps and room air-conditioners in 2021.

Room air-conditioners and heat pumps have been accounted for in the inventory since 2007. Data on the annual sales of room air-conditioners and heat pumps were requested from FRIXIS, previously UBF-ACA (Air-conditioning Association). FRIXIS is the most representative organisation of market players in this sector. Sales data are available for 2005-2021. The total quantity of equipment placed on the market was split among the different categories used for the inventory (i.e. heat pump boilers, RAC > 7 kW and RAC < 7 kW). Movable air-conditioning and chillers placed on market were estimated differently.

- **Movable air-conditioning**

The number of movable air-conditioning equipment is estimated based on extrapolations based on statistics from UBF-ACA. An adjustment of the stock was made based on the household budget enquiry providing statistics on the number of households and number of equipment per household of small movable air-conditioning appliances[10]. The average lifetime is assumed to be 15 years.

The average quantity of refrigerants in movable air-conditioning is 1 kg. While initially, air-conditioners used R407C and R410A, from 2020 all movable air-conditioning are equipped with R290. No manufacturing emissions are assumed. The lifetime emission factor is 2,5% per year [12]. As for refrigerators, it is assumed that a substantial part of the equipment is disposed incorrectly and/or refrigerants are losed during transport, resulting in an assumed disposal emission factor of 70%.

Table 4-16. Share of ownership of movable air-conditioning in Belgium.

	Belgium	Flanders	Walloon region	Brussels
2016	5% (0.06 – 1.15)	5% (0.06 – 1.16)	5% (0.06 – 1.12)	5% (0.06 – 1.25)
2018	5% (0.06 – 1.09)	5% (0.05 – 1.10)	5% (0.05 – 1.07)	8% (0.09 – 1.09)
2020	8% (0.09 – 1.13)	8% (0.09 – 1.09)	8% (0.10 – 1.22)	8% (0.09 – 1.10)

Note: Share of households with equipment (average number of equipment all households – average number of equipment households that own movable air-conditioning.

Source: Household budget enquiry, 2022.

[10] https://statbel.fgov.be/en/themes/households/household-budget-survey-hbs#panel-12

Table 4-17. Comparison of assumptions for movable air-conditioning between selected countries (in 2022).

Assumption	Belgium	France	Germany	UK
Charge (kg)	0,5 - 1	0,5	NA	0,5 – 8
Lifetime (yr)	15	10	10	12
Manufacturing EF (%)	NA	1,5 – 2,5%	NA	3%
Operational EF (%)	2,5%	2%	2,5%	5%
Disposal EF (%)	70%	50%	60%	80%

SOURCE: INFORMATION TAKEN FROM NIR (https://unfccc.int/ghg-inventories-annex-i-parties/2022).

➢ Room air-conditioners and heat pumps

Data were received from the only manufacturer of air-conditioning and heat pumps in Belgium on refrigerant use and emissions during manufacturing of heat pumps and room air-conditioners in 2021. All manufacturing emissions are allocated to this sub-sector. Sales statistics from FRIXIS and UBF-ACA have used different clasifications. For the inventory the sales statistics are split into two categories: room air-conditioners smaller than 7kW and room air-conditioners larger than 7 kW. This also includes heat pumps.

Assumptions on the characteristics of room air-conditioning were based on the French and German F-gas inventories.

Table 4-18. Assumptions for room air-conditioners and heat pumps and comparison with the IPCC 2006 Guidelines.

	RAC and heat pumps	IPCC (2006)[1]	2019 refinement
Charge (kg)	0,5 – 6,2 kg	0.5 < M < 100	0.5 < M < 100
Lifetime (y)	15	10 < d < 20	10 < d < 20
Manufacturing EF (%)	NR	0,2 < EF < 1	0,2 < EF < 1
Operational EF (%)	2,5 - 5%	1 < EF < 10	1 < EF < 10
Recovery efficiency (%)	30%	0 < RE < 80	0 < RE < 80

Note: [1] Residential and commercial, including heat pumps.

Table 4-19. Comparison of assumptions for room air-conditioning between selected countries.

Assumption	Belgium	France	Germany	UK
Charge (kg)	1,6 - 5	2,5 - 15	NA	2 - 100
Lifetime (yr)	15	15 - 20	10 – 13	15 – 18
Manufacturing EF (%)	0,02%	1,5 – 2,5%	NA	2%
Operational EF (%)	4 – 5%	2 – 5%	5%	5%
Disposal EF (%)	70%	35%	20 – 40%	55%

NOTE: FRANCE, GERMANY AND UK DISTINGUISH BETWEEN HEAT PUMPS (HEAT ONLY) AND ROOM AIR-CONDITIONING (COOLING WITH OR WITHOUT HEATING). FOR BELGIUM STATISTICS ARE NOT AVAILABLE TO MAKE THIS SPLIT.

SOURCE: Information TAKEN FROM NIR (https://unfccc.int/ghg-inventories-annex-i-parties/2022).

➢ Chillers

Chillers used to be considered under ‘Industrial and commercial installations’, however a 2018 study from VITO, Econotec and Oeko-Recherche [8] showed that most chillers are prefilled. We therefore included them in the category stationary air-conditioning.

Sales statistics were available for the period 2005-2011 from UBF-ACA. For the period 2012-2021, the number of chillers placed on the market was estimated based on the total sales of air-conditioning and heat pumps. This corresponds well with estimates made for Belgium by BSRIA[11].

Assumptions on the characteristics of chillers were taken from the French and German F-gas inventories. Often a distinction is made between categories, but because statistics are not available averages are used for all chillers. BSRIA[20] assumed that approximately 60% of chillers are below 100 kW and 40% larger than 100 kW. An average lifetime of 15 years was assumed.

The share of refrigerants since 1998 was reconstructed based on the available literature (e.g., from France, Germany, and the UK). This shows changing shares of R407C, R404A and R134a over this time frame. In recent years, the increasing share of R410A is most important. An average load of 100 kg is used, but this hides a much wider variation in loads depending on the capacity of the chiller.

Based on these data and assuming an average lifetime of 15 years, the total stock of equipment in Belgium is calculated. Assumptions made by Schwarz [13] were used to estimate the quantity of refrigerants per unit.

The estimated consumption of R407C and R410A from chillers (but also other users such as room air-conditioning) is lower than the total supply of these gases on the Belgian market. As these gases are almost exclusively used for stationairy air-conditioning, these are now allocated to the sector chillers.

Table 4-20. Assumptions for chillers and comparison with the IPCC 2006 Guidelines.

	chillers	2019 refinement
Charge (kg)	70	10 < M < 2000
Lifetime (y)	15	15 < d < 30
Manufacturing EF (%)	NA	0,2 < EF < 1
Operational EF (%)	3.8%	2 < EF < 15
Recovery efficiency (%)	30%	0 < RE < 95

Table 4-21. Comparison of assumptions for chillers between selected countries.

Assumption	Belgium	France	Germany	UK
Charge (kg)	70	0,3 kg/kW	NA	30 – 1500
Lifetime (yr)	15	15 - 25	15 – 25	15 – 21
Manufacturing EF (%)	NA	1,5 – 2,5%	0,5 - 1%	2%
Operational EF (%)	3,8%	3,3 – 5%	2,8%	5%
Disposal EF (%)	70%	15%	20%	50%

SOURCE: Information TAKEN FROM NIR (https://unfccc.int/ghg-inventories-annex-i-parties/2022).

11 Daikin, Pers. Comm., 2018.

The disposal emissions are assumed to be 70% [13].

- **Heat pump boilers**

Sales statistics are taken from UBF-ACA and FRIXIS. Sales of heat pump boilers started in 2008 and have increased steadily since then. In 2021 more than 8000 were installed. We assume that boilers have an average lifetime of 15 years. This means that disposal and related emissions have not yet occurred.

Heat pump boilers mainly use HFC-134a as refrigerant. For simplification, 100% of heat pumps are assumed to be equipped with HFC-134a and a charge of 800 g. Heat pump boilers are hermetically-sealed systems and emissions during use are not high so an emission factor of 2% is assumed.

- **Heat pump tumble dryers**

Heat pump dryers have been on the EU market since 2004 and their penetration is increasing. In Switzerland 100% of the tumble dryers are heat pump dryers (data from the Swiss Association of the Domestic Electrical Appliances Industry cited in (topten.eu, 2014)). The share in the EU is lower though. In Germany, it was estimated to be 39% in 2012.

Based on collected information, we estimated the scale of emissions from heat pump dryers in Belgium.

It is assumed that 60% of households have a tumble dryer, based on the household budget survey of 2010. In more recent version, share of households with tumble dryer are not included. The share of heat pump dryers sold is assumed to be similar to Germany: 56% of sold tumble dryers in 2014 and assuming similar growth numbers 92% in 2019 .

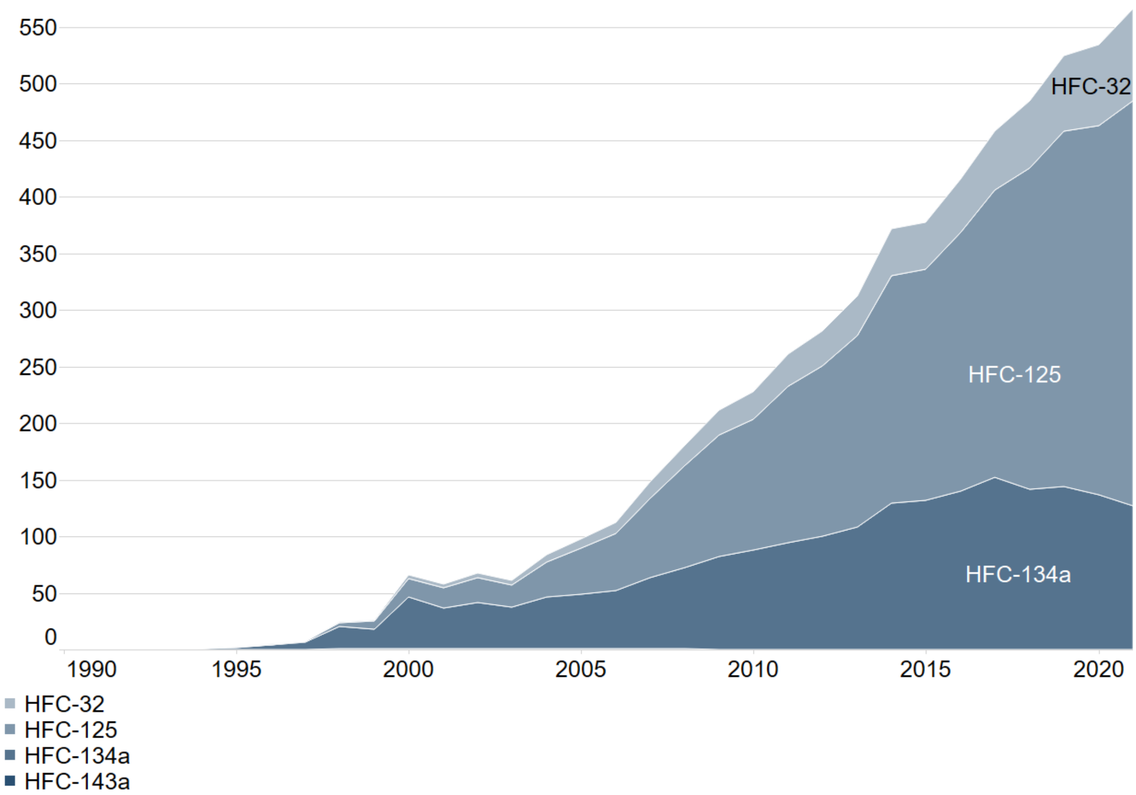
Dryers are equipped with either HFC-134a, R407C or R290, with quantities ranging between 220 and 430 g (Federal Environment Agency, 2014). An average quantity of 300 g is assumed. The systems are hermetically sealed and for the German inventory in 2014 the operation emission factor is 0,3%, which we have used as well, although the Swiss inventory uses an annual operation emission factor of 2%.

The share of heat pump dryers equipped with HFC-134a, R407C or R290 is not known exactly. In Finland the assumption is that 70% of heat pump dryers are equipped with HFC-134a and 30% with R407C. HFCs have been predominantly used in tumble dryers, but as predicted by (Bellomare & Minetto, 2015), they have been increasingly replaced by alternatives. Companies are switching to alternatives, such as propane, which has been used since 2015 (German NIR, 2022). For 2021 we have assumed shares of 46% HFC-134a, 20% R407C and 35% R290.

Results

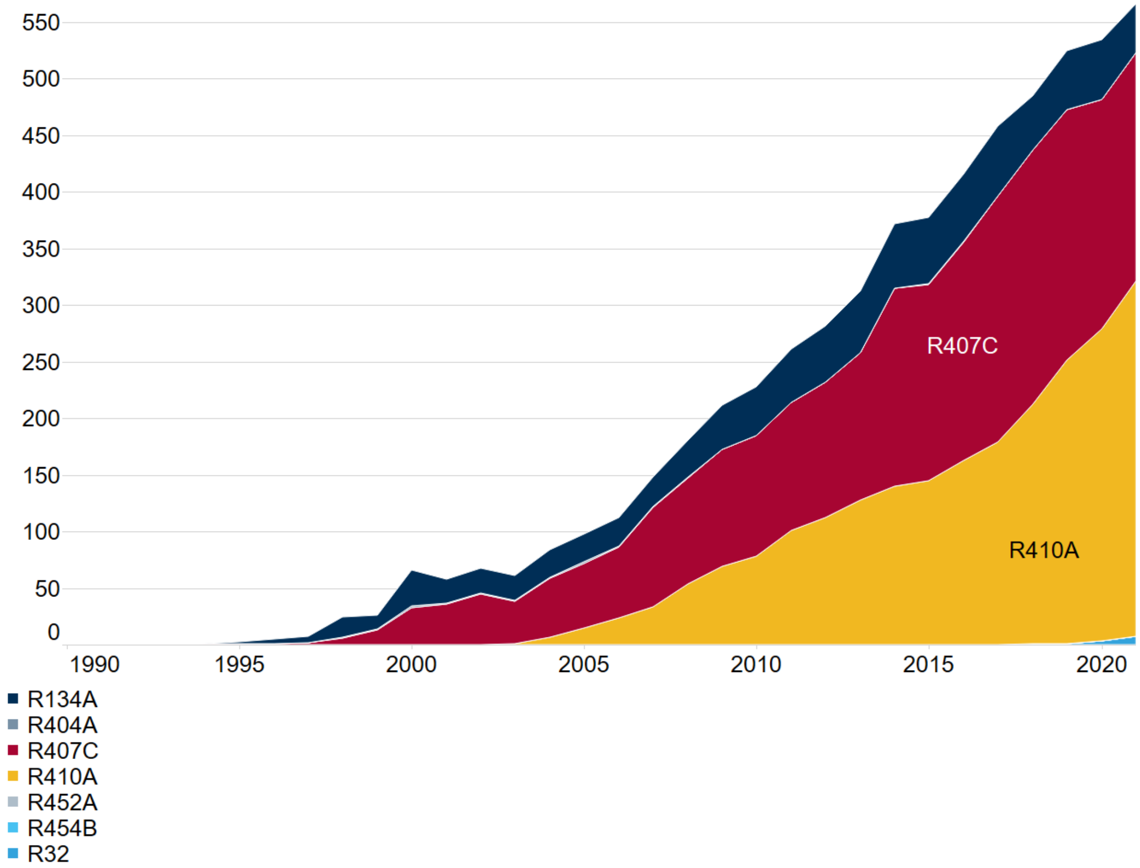
The results are shown below. In recent years, R410A has surpassed R407C as most frequently used refrigerant, this is mainly due to the F-gas regulation. Another trend is the increased use of R32, especially for products in lots 1 and 21.

Figure 4-20. Emissions of CRF F-gases from stationary air-conditioning per substance (in kt CO_2-eq).



Source: VITO, Econotec (own calculations, 2022).

Figure 4-21. Emissions of CRF F-gases from stationary air-conditioning per refrigerant (in kt CO_2-eq).



Source: VITO, Econotec (own calculations, 2022).

Figure 4-22. Emissions of CRF F-gases from stationary air-conditioning per sub-sector in 2021 (in kt CO_2-eq).

Source: VITO, Econotec (own calculations, 2022).

Table 4-22. Emissions of F-gases from stationary air-conditioning (kton CO_2-eq.).

	1990	1995	2000	2005	2010	2015	2020	2021
ODS	**237,9**	**526,4**	**648,9**	**541,9**	**457,2**	**199,0**	**0,0**	**0,0**
HCFC	**237,9**	**526,4**	**648,9**	**541,9**	**457,2**	**199,0**	**0,0**	**0,0**
HCFC-22	237,9	526,4	648,9	541,9	457,2	199,0	0,0	0,0
HCFC-141b	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
CRF F-gases	**0,0**	**2,6**	**66,0**	**97,4**	**227,5**	**377,6**	**533,9**	**566,0**
HFC	**0,0**	**2,6**	**66,0**	**97,4**	**227,5**	**377,6**	**533,9**	**566,0**
HFC-32	0,0	0,1	3,1	8,1	23,9	42,1	71,4	81,7
HFC-125	0,0	0,4	16,6	40,3	116,2	204,1	326,0	357,1
HFC-134a	0,0	2,0	45,2	48,5	87,2	131,2	136,5	127,2
HFC-143a	0,0	0,0	1,1	0,6	0,2	0,2	0,0	0,0
Other F-gases	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**
HFO	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**
HFO-1234yf	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Total	**237,9**	**529,0**	**715,0**	**639,3**	**684,8**	**576,6**	**533,9**	**566,0**

Source: VITO, Econotec (own calculations, 2022).

4.5 Closed cell foam (2.F.2.)

4.5.1 Closed cell foam (2.F.2.a)

Introduction

The following types of closed cell foam are taken into consideration:

- extruded polystyrene foam
- polyurethane foam (panels or blocks)
- 2 component spray foam
- refrigerator insulation.

The first three are manufactured in Belgium, while the last one is only imported in the equipment.

Methodology

The figures for the consumption of foaming agents are collected directly from the relevant companies and obtained separately for the manufacture of polyurethane foam (PUR) and extruded polystyrene (XPS).

The modelling of emissions is based on an annual inquiry among the foam manufacturers on their consumption of blowing agents, and on assumptions on emission rates for manufacturing and product use, as well as on external trade, by type of insulation foam.
The emissions from closed cell foams are calculated from:

- the annual consumptions of fluorinated greenhouse gases by the manufacturers;

- assumptions on assembly emission factors;
- assumptions about the relative share of external trade;
- assumptions about the emission factors from the foam bank.

The end-of-year bank of fluorinated greenhouse gases is calculated annually, by substance, from the end-of-year bank of the year before, the quantity added to the bank and the emission from the bank.

The figures for the consumption of foaming agents used to be obtained from Federplast.be (Belgian Association of Plastics and Rubber Converters), separately for the manufacture of polyurethane foam (PUR), One-Component-Foam (OCF) and extruded polystyrene (XPS). For 2013 and the subsequent years they were obtained directly from the companies or from the official emission reporting by the companies.

As refrigerators are not manufactured in Belgium, emissions from domestic refrigerator foams are evaluated in a similar way as emissions from refrigerator refrigerants, based on a model of the refrigerator stock. The foam of domestic refrigerators and freezers contains HFC-245fa. The emissions of Kyoto protocol gases are rather negligible.

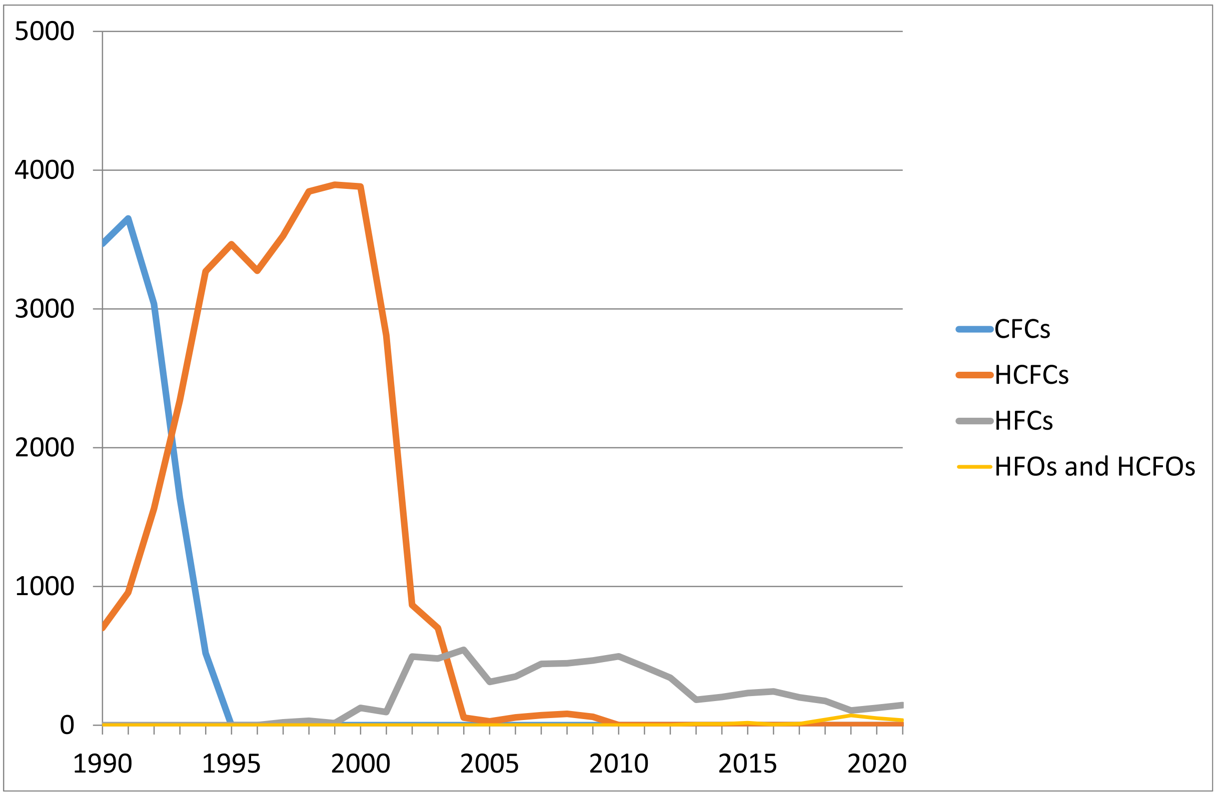
The recovery or destruction of fluorinated greenhouse gases from insulation foams only takes place for refrigerator/freezer foams. Given the long lifetimes of insulation foams in buildings, the fact that such foams are considered to have started to be used only in 1976 and the lack of statistics on recovery of such foams in demolished buildings, no disposal has been considered in the emission inventory. However, since foams from any demolished buildings are generally dumped on a landfill rather than incinerated, and therefore continue to cause emissions, the calculation is probably realistic.

Results

Figure 4.23 below recalls that HCFCs, which had been used in very large quantities in the past, had practically disappeared by 2004, because of European Regulation 2037/2000. They were only very partially replaced by HFCs, which are mainly used for XPS foam, and now also for PU 2-component spray foam. Meanwhile, a small amount of HFOs and HCFOs is being used (36 t in 2021): HFO-1234ze(E) since 2013 and HCFO-1233zd and HFO-1336mzz(Z).

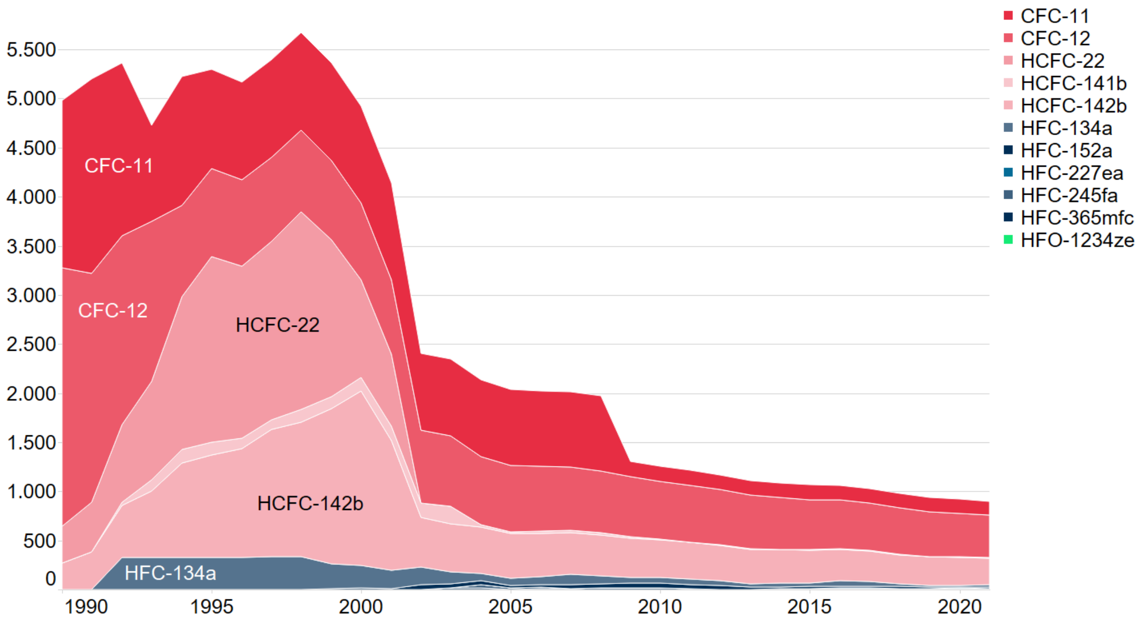
The evolution of emissions in terms of CO2-equivalent is shown on Figure 4-24, where one can notice the impact of the regular decline of existing stocks of CFCs and HCFCs, which are still dominant.

Figure 4-23. Consumption of F-gases for foam manufacturing (in t).



SOURCE: VITO, ECONOTEC (OWN CALCULATIONS, 2022).

Figure 4-24. Emissions of F-gases from closed cell and open cell foams in Belgium (in kt CO_2-eq).



Source: VITO, Econotec (own calculations, 2022).

4.5.2 Open cell foam (2.F.2.b)

Introduction

Belgium is a large producer of polyurethane cans ('one component foam') and its production is almost completely exported. However, CO_2-equivalent emissions of HFCs from this sector, which arise both during manufacturing and as a result of their use, have been drastically reduced since 2008, as EU Regulation 842/2006 and EU Regulation 517/2014, which replaced it, have prohibited the sale in the EU of 'one component foams' containing mixtures with a GWP of 150 or more, except when required to meet national safety standards.

Methodology

The emissions during manufacturing are based on data obtained from the manufacturer. The residual emissions of HFCs contained in polyurethane cans sold in Belgium are based on per capita data for Germany.

Results

For confidentiality reasons, the emissions are not reported to UNFCCC, the data are aggregated with those of closed cell foams.

4.6 Fire protection (2.F.3.)

Introduction

Manufacturers of fixed suppression systems for firefighting have been using HFCs as an alternative to halons for many years. HFC-based systems are used for the protection of electronic and telecommunications equipment, and in military applications, records offices, bank vaults and oil production facilities. The main HFC used in fixed systems are HFC-227ea and HFC-125.

Methodology

Manufacturing emissions are estimated to be 0,1% for all quantities installed in bulk. Not all information was received yet and sector has not been updated yet.

Disposal emissions are taken into account. Although some companies reported recovery of HFCs from dismantled installations, this data is not used. We rather use modelled quantities in equipment that has reached the end of lifetime, for which an emission factor of 10% is used. Most of these emissions are arising from reclamation at reclamation sites and not from dismantling.

Table 4-23. Comparison of assumptions between selected countries.

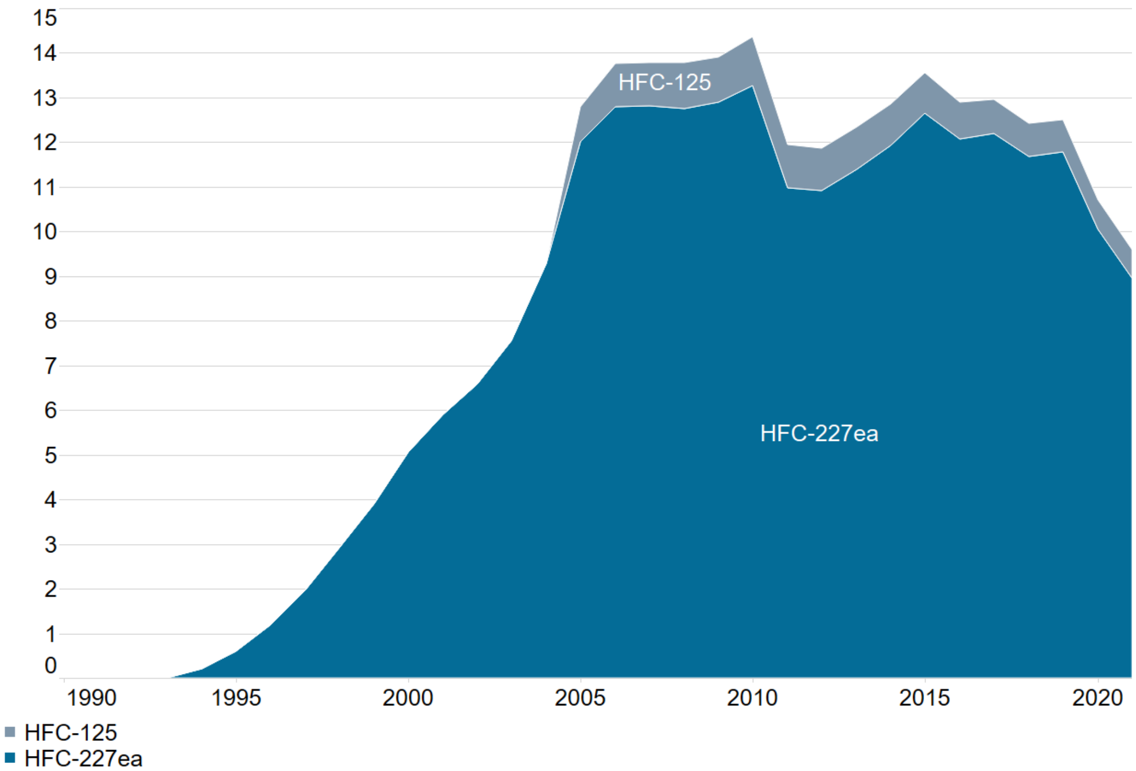
	Belgium	Germany	France	UK	Sweden
Lifetime (yr)	**20**	**20**	**NA**	**20**	**10**
Manufacturing EF (%)	**0.1%**	**NA**	**NA**	**0%**	**0.5%**
Operational EF (%)	**2.3%**	**2.5% - 4%[1]**	**NA**	**1% - 1.5%[2]**	**0.1% - 2%[3]**
Disposal EF (%)	**10%**	**1%**	**NA**	**0.1%**	**5%**

Note: [1] 2.5% HFC-227ea, 4% HFC-236fa, HFC-23; [2] 1% servicing, 1.5% fire (lifetime); [3] 0.1% HFC-227ea, 2% other HFCs

Source: Information taken from NIR (https://unfccc.int/ghg-inventories-annex-i-parties/2022).

Results

Figure 4-25. Emissions of CRF F-gases from fire extinguishers in Belgium (in kt CO_2-eq).



Source: VITO, Econotec (own calculations, 2022).

4.7 Aerosols (2.F.4.)

4.7.1 Metered dose inhalers (2.F.4.a.)

Introduction

The only manufacturer of MDIs in Belgium having stopped producing CFC or HFC containing products, there are no manufacturing emissions anymore since 2006. The only emissions left are those produced during the use or disposal of MDIs.

Methodology

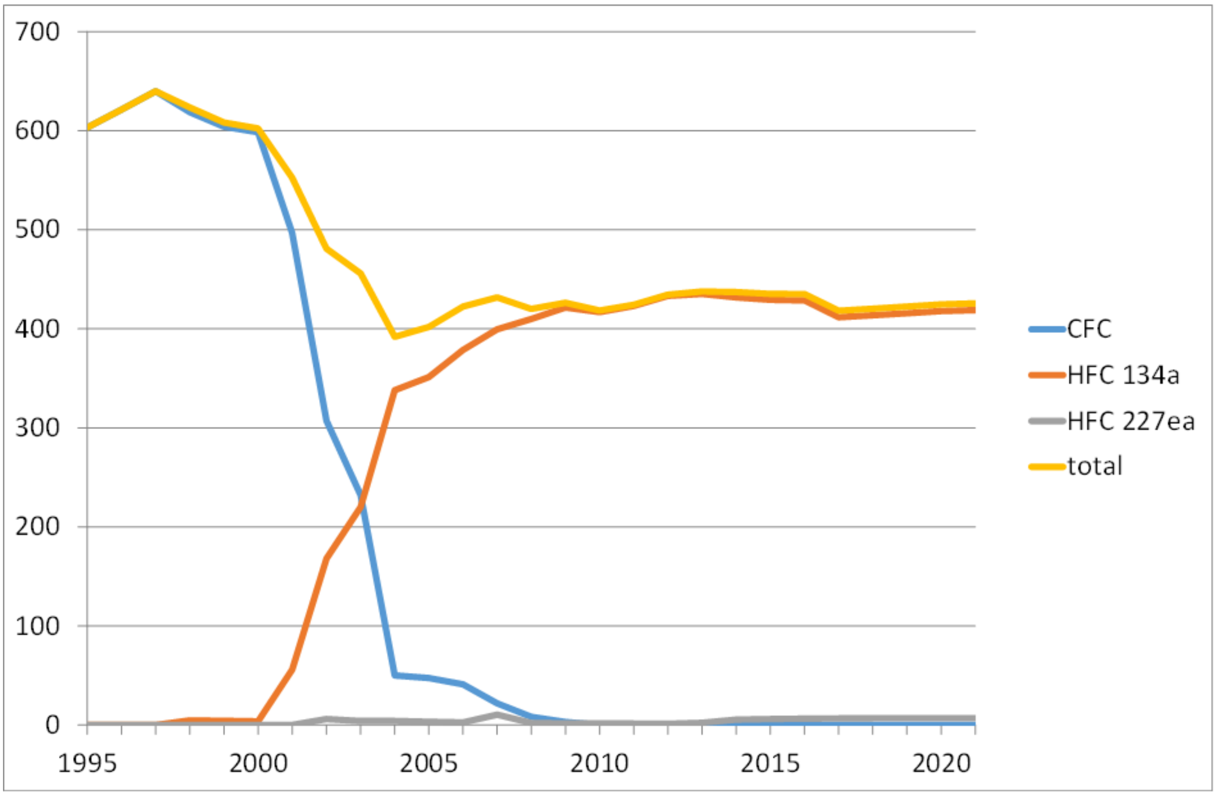
The emissions resulting from the consumption of MDI are based on data on annual sales of MDIs in Belgium, both in terms of number of units and number of doses. The emissions are estimated on the basis of the type of gas used in each pharmaceutical product and on assumptions on the average quantity of fluorinated gas per dose.

For up to the year 2008, the figures of annual sales of MDIs in Belgium had been purchased from the market research company IMS Health, both in terms of number of units and number of doses. Figures for 2009-2017 were obtained from GSK through the Flemisch government (Pers. Com. Sven Claeys, VEKA, 9/12/2014 and 29/11/2018). The figures for 2018-2021 were obtained by applying to those of 2017 the population growth.

Results

The figure below shows the development since 1995. Overall, after a stabilisation during the years 2012-2016, a small decline has been observed in 2017.

Figure 4-26. Number of MDI doses sold in Belgium (million).



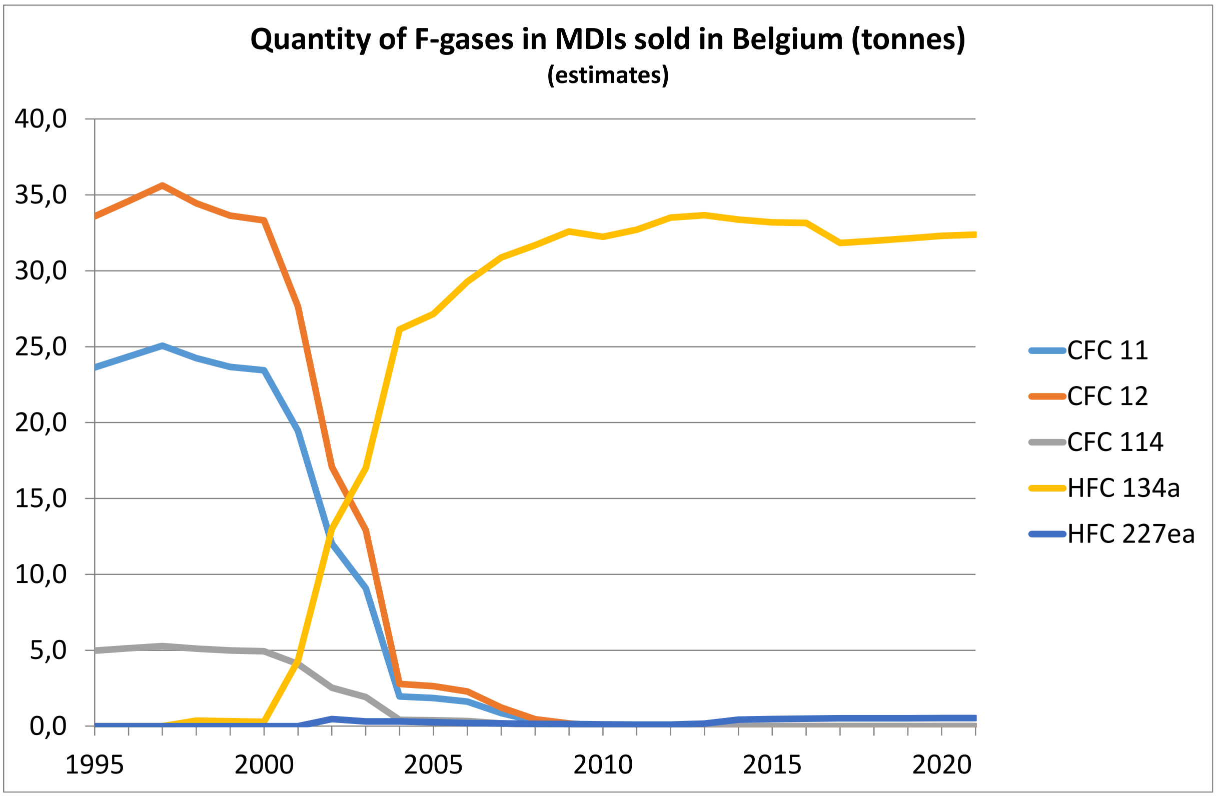
Source: VITO, Econotec (own calculations, 2022).

The emissions, shown on Figure 4-28, have been estimated based on the type of gas used (found in the Compendium of pharmaceutical products, from pharma.be) and on assumptions on the quantity of F-gas per dose, taken from the literature.

There is uncertainty on the value of the latter parameter, however. Given the growing concern about climate change, various studies have been published in recent years on the carbon footprint of MDIs. We have used this opportunity to review the available data on F-gas consumption per dose. Unfortunately, Information on the amount of HFA propellant in MDIs is not publicly available [18]. Besides, in the literature there is confusion about the meaning of a dose. In its 2010 MTOC Assessment Report, UNEP mentions ‘carbon footprints per 200 doses’ (p. 16) which in its 2014 and 2018 reports it considers as ‘carbon footprints per 100 doses’, one dose for an MDI being 2 actuations. This doubling of the footprint per dose arises from the fact that 2 actuations (puffs) of MDI are considered necessary to equate 1 actuation of DPI (dry powder inhaler).

In the emission inventory we have up to now assumed 75 mg HFC/actuation. For the sales of MDI trademarks sold in Belgium for which a carbon footprint per actuation is known, we evaluated an average consumption of about 100 mg HFC/actuation. However, this only covers 39,5% of sales in 2017. And the uncertainty is large. In Fulford [19], carbon footprints vary differ from 49 to 170 g CO_2-eq according to the different trademarks. Given these circumstances, we have not changed our assumption for the time being.

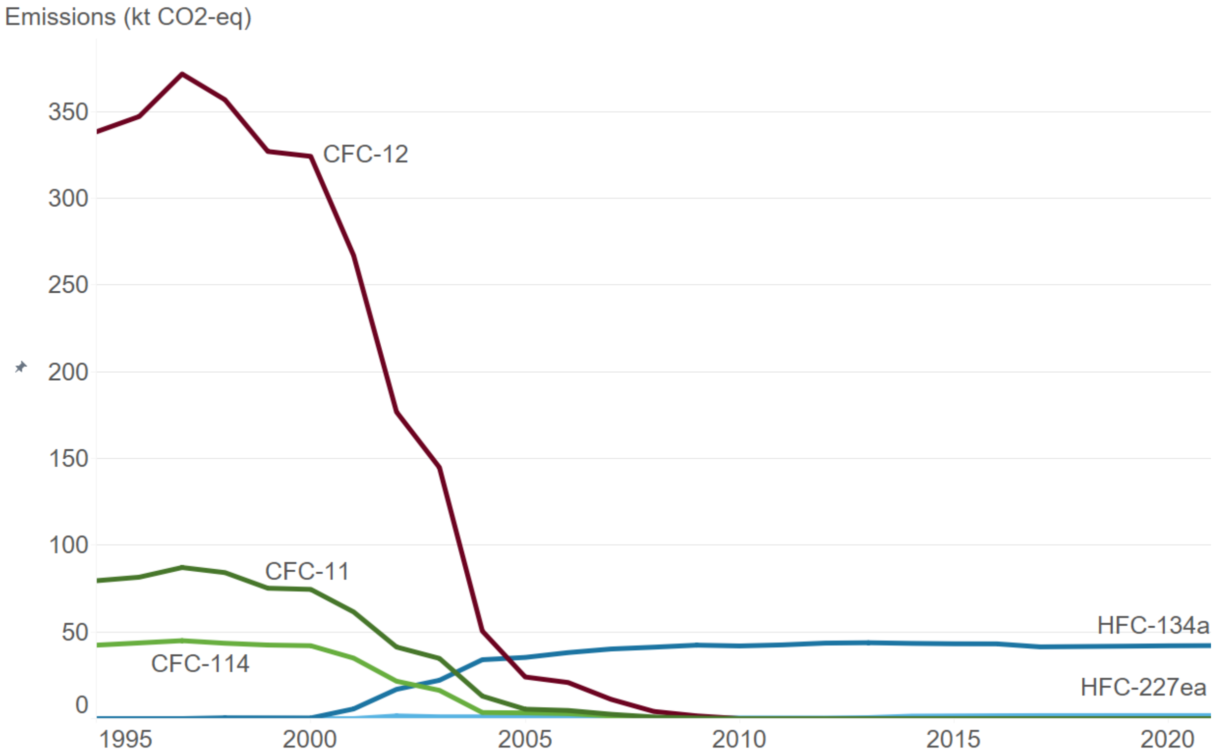
Figure 4-27. Quantity of F-gases in MDIs sold in Belgium (in t).



Source: VITO, Econotec (own calculations, 2022).

In terms of greenhouse gas emissions, the evolution is shown on Figure 4-28. In 2021 the emissions reached 44 kt CO_2-eq.

Figure 4-28. Emissions of F-gases from the use of MDIs in Belgium (in kt CO_2-eq).



Source: VITO, Econotec (own calculations, 2022).

4.7.2 Other aerosols (2.F.4.b.)

Introduction

Aerosols typically use hydrocarbon propellants but a small proportion of the market use other volatile liquids such as dimethyl ether (DME) and HFCs. HFCs are used only in a few applications where the use of a more expensive propellant is required to provide a non-flammable material. The most important industrial applications in volume terms are air dusters and pipe freezing products; other applications include specialised lubricants and surface treatments, and specialised insecticides [20]. Technical aerosols that contain HFCs with GWP of 150 or more, except when required to meet national safety standards or when used for medical applications are prohibited since 2018. The use of HFCs for novelty applications for entertainment and decorative purposes and signal horns containing HFCs with GWP of 150 or more are prohibited from 2009 onwards.

Methodology

Up to 2012 we received data from DETIC of HFCs (HFC-134a and HFC-152a) used in Belgium to produce spray cans designed for the European market. DETIC aggregated information received from 4 companies. However, DETIC informed us that from 2013 they would no longer request and aggregate this information. We contacted all companies involved but did not receive information from all of them (some did not want to disclose information due to confidentiality). We therefore used information from the

Flemish IMJVs[12] for 2020, which was split between HFC-134a and HFC-152a. Reporting is now limited to one company and HFC-152a as use of HFCs with a GWP of more than 150 is prohibited for most technical aerosol applications.

Losses from manufacturing are, according to DETIC, very small. However, no quantitative information was given. For the F-gas inventory in Germany an emission factor of 1,5% is assumed [13], which has also been accepted for the Belgian data and confirmed by DETIC for the period before 2013 and which is also used for the period afterwards. This emission factor was used to calculate the consumption of HFCs.

It is an emission source for which there remains quite a lot of uncertainty, because there are no data on the actual consumption of technical aerosols in the country. Alternatively, consumption cannot be estimated from production and trade, as no external trade figures are available. The consumption is also very diffuse, for a variety of sources of small magnitude.
Current estimates of emissions associated with the use of technical aerosols in Belgium are based on German per capita quantities. For Germany, general aerosols import and export are considered by Öko-Recherche to be balanced; therefore, the consumption can be estimated from the production. Emissions in the German inventory are available up to 2018. These per capita emissions have changed in the most recent inventory available and declined from 2,87 g/person in 2006 to 1,87 g/person in 2014 and 0,13 g/person in 2019. For 2021, the same emission factor as for 2020 is assumed, 0,03 g/person.

Results

The emissions significantly drop in 2018, when ban on the use came into effect. Emissions in 2021 are estimated to be 0,36 t or 0,47 kt CO_2-eq, a reduction of almost 94% compared to 2017.

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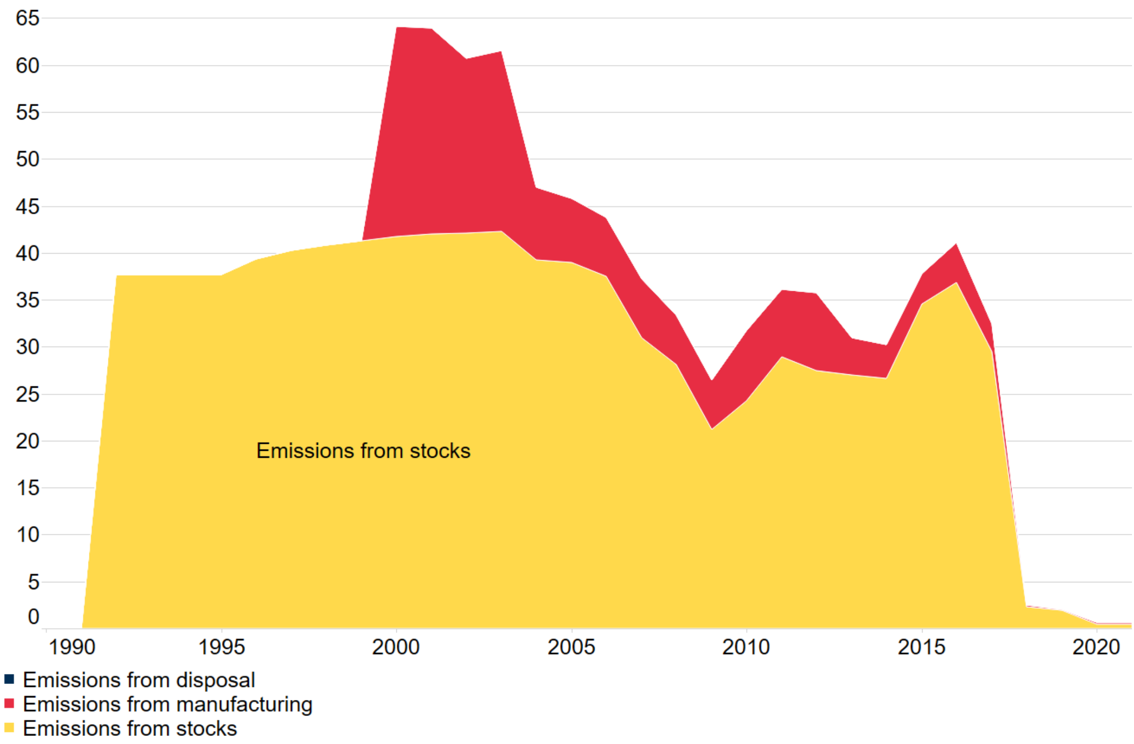
12 IMVJ: Integraal Milieu Jaarverslag.

Figure 4-29. Emissions of CRF F-gases from the use of technical aerosols in Belgium (in kt CO_2-eq).



SOURCE: VITO, ECONOTEC (OWN CALCULATIONS, 2022).

4.8 Solvents (2.F.5.)

Introduction

Since 1st January 2002, European Regulation 2037/2000 has forbidden the use of HCFCs for all solvent uses, except for precision cleaning of electrical and other components in aerospace and aeronautics applications. However, for the latter, the prohibition has entered into force on 31st December 2008. Therefore, we consider these emissions to be zero.

HFCs can be used as solvents in a range of applications such as precision cleaning to replace CFCs, HCFCs or 1,1,1-trichloroethane in sectors such as aerospace and electronics. While there was a substantial shift towards other organic solvents, a small residual market remains for HFC-based solvents, with HFC 43-10-mee being the main HFC-based product. Other products are used in production processes such as the semiconductor, the liquid crystal display and the photovoltaic industries. See relevant sections above.

4.9 Electrical equipment (2.G.1.)

Introduction

Switchgear are a combination of switches, fuses or circuit breakers that control, protect and insolate various types of electrical equipment e.g. by avoiding current overload [21].

The medium that provides insulation in a switchgear can be either air, gas, solid or liquid material. In the case of gas insulated switchgear (GIS), typically SF6 is used. SF6 has been used in high and medium voltage switch gear and transformers since the mid-1960s. The physical properties of the gas make it highly effective as an arc-quenching medium and as an insulator. Consequently, it has gradually replaced equipment using older technologies, namely oil filled and air blast equipment. Currently, there are alternative technologies to using SF6 already commercially available or under development, albeit not for all applications and it will take time to build up the production capacity to serve the full European market [21].

Methodology

We received data from ELIA and SYNERGRID. Data from production sites are small and do not change considerably over time. SF6 use in wind turbines was added based on the number of wind turbines installed in Belgium in 2021.

We have taken manufacturing emissions on board for the entire time series. To do this, we have assumed that the increase in the bank of SF6 (for production, transport, and distribution) in the period 1990-2021 is caused by new installations and that there is no disposal of SF6 in this period. An emission factor of 1% is used.

ELIA and SYNERGRID provided information on the use and emissions of SF6 in 2021.

FEBEG reported the stock of SF6 in all large power stations in 2016 and the average quantity in switchgear in wind turbines, which was also used in 2021 (data from FEBEG is consistent in time). We have included these quantities also in the stock data, using data on the number of wind turbines installed in Belgium (onshore and offshore).

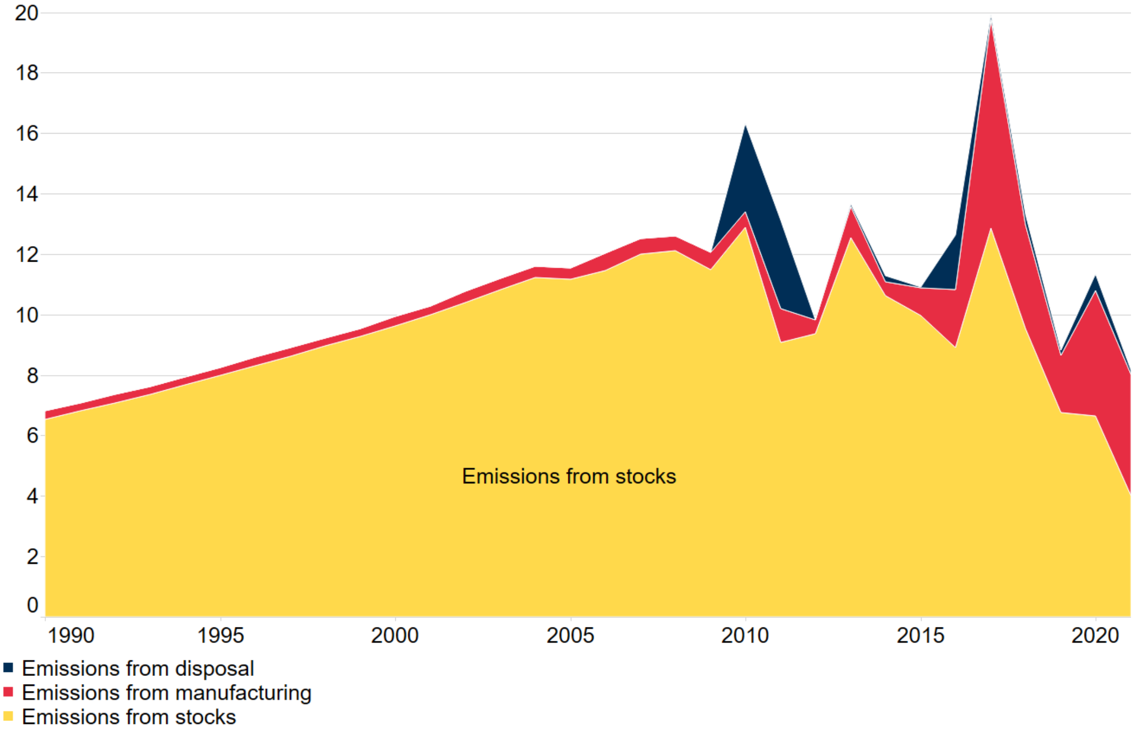
The operation emission factor for SF6 in the subsector production was adjusted, based on data provided by FEBEG. FEBEG reported that the emission factor for new installations is 0,1% and 1% for older installations. As most installations are recent, the average emission factor is 0,11% in 2021[13].

Results

SF6 emissions from electrical switchgear fluctuate from year to year, but does not seem to increase or decrease. In 2021 total emissions were 8 kt CO_2-eq. The average emissions of the last 15 years is 12,4 kt CO_2-eq. In this 15-year period the bank of SF6 in switchgear increased with a factor of 2,7. This difference in trends can be explained by the measures taken by especially ELIA to limit SF6 emissions.

13 FEBEG reported that for a number of installations the emission factor was 0. For all these cases we have adjusted this value to 0,1%.

Figure 4-30. Emissions of SF6 from switchgear in Belgium (in kt CO_2-eq).



Source: VITO, Econotec (own calculations, 2022).

4.10 SF6 and PFCs from Other Product Use (2.G.2.)

4.10.1 Particle accelerators (2.G.2.b.)

Introduction

The insulating gas SF6 is used to protect human safety and to safeguard equipment parts (to guard against burning of insulators). In relevant applications, high-voltage parts are insulated by being enveloped with the gas (which guards against electrical arc flashes between high-voltage parts and equipment walls).

In some cases, such protection can also be achieved by using other gases (such as nitrogen, nitrogen/CO_2 mixtures), by providing adequate physical distance (air insulation) or by enclosing equipment in concrete walls. The criteria entering into decisions for or against SF6 as an insulating gas for equipment (either by itself or as an additive) include technical circumstances, design considerations and voltage levels. For this reason, the quantities of SF6 that non-standardised equipment and components require will vary. The SF6 charge in any given unit or system thus depends on the unit's/system's setup, and not on its size class (measured in MV, for example).

The SF6-insulated particle accelerators in use differ in terms of size, design and function. High-voltage accelerator systems (0,3 to more than 23 MV) are used by university institutes, research groups and industry. In such high-voltage systems, the accelerator and the high-voltage source (Van de Graaff generator, or a more-compact high-voltage generator with cascaded diodes) sit within a tank that is insulated with SF6 or an SF6-containing mixture. In some cases, such tanks are also pressurised. Such tanks often have to be opened when equipment has to be adjusted or repaired. In such cases, the insulating gas is pumped into reserve tanks. SF6 losses occur during such pumping, and they occur whenever overpressure valves of accelerator or reserve tanks are activated. Research accelerators, which are operated under varying conditions, have to be opened more frequently than industrially used electron accelerators do.

In industry, low-voltage devices with less than 0,3 MV are also used. In low-voltage systems, the depth to which electrons penetrate materials being processed is considerably lower than the depths occurring in connection with high-voltage systems. In industry, "electron-beam tools" are used for cross-linking of polymers, primarily polymers in cable and wire insulation. Low-voltage systems, with lower accelerator voltages, require less shielding (= smaller quantities of SF6) than high-voltage systems do.

Yet another relevant category consists of radiation-therapy devices in medical facilities. In cancer treatments with electron or photon radiation, industrially pre-set particle accelerators are used. Such accelerators accelerate particles within waveguides that are filled with the insulating gas SF6, which guards against electrical flashovers. Prior to 1996, CFCs were used in such equipment.

SF6 is also used as an insulating gas in large electron microscopes (with accelerator voltages >100 kV) and in electron-beam lithography systems. Such devices, which are combined within the category "other equipment, have now been covered for the first time – for the year 2010.

In general, the following applies: The SF6 consumption tied to initial charging and recharging of equipment, and to replacements of emission, depends on equipment size, pressure conditions and operating conditions.

Methodology

Not included in the inventory.

4.10.2 Soundproof windows (2.G.2.c.)

Introduction

Since 1975, SF6 has been inserted into the spaces between multi-pane windows to enhance the soundproofing properties.

Regulation 842/2006/EC, replaced by EU Regulation 517/2014 [10], has prohibited the placing on the market of windows containing SF6 in July 2007 for domestic use and in July 2008 for other windows. Both main manufacturers of acoustic double glass had stopped using SF6 in 2006, the only smaller manufacturer still using SF6 in 2007 did not use it from 2008 onwards.

Methodology

For the calculation of emissions, we used the IPCC 2006 guidelines [1]. Data on manufacturing emissions were calculated based on the consumption of SF6 by glass producers and an annual emission factor of 33%.

To calculated operational emissions, we assume that around 1% of the SF6 bank, i.e. SF6 contained in installed double glazing in Belgium, is emitted annually.

We assumed a linear increase of disposal emissions with 0,32 t per year between 2001 and 2012. After 2012, disposal emissions were calculated based on the estimated quantities installed 25 years before. The disposal emission factor is 100%.

Equation: Emissions from soundproof windows

$$Assembly\ Emissions\ in\ year\ t = 0.33\ \times SF6\ purchased\ to\ fill\ windows\ assembled\ in\ year\ t$$

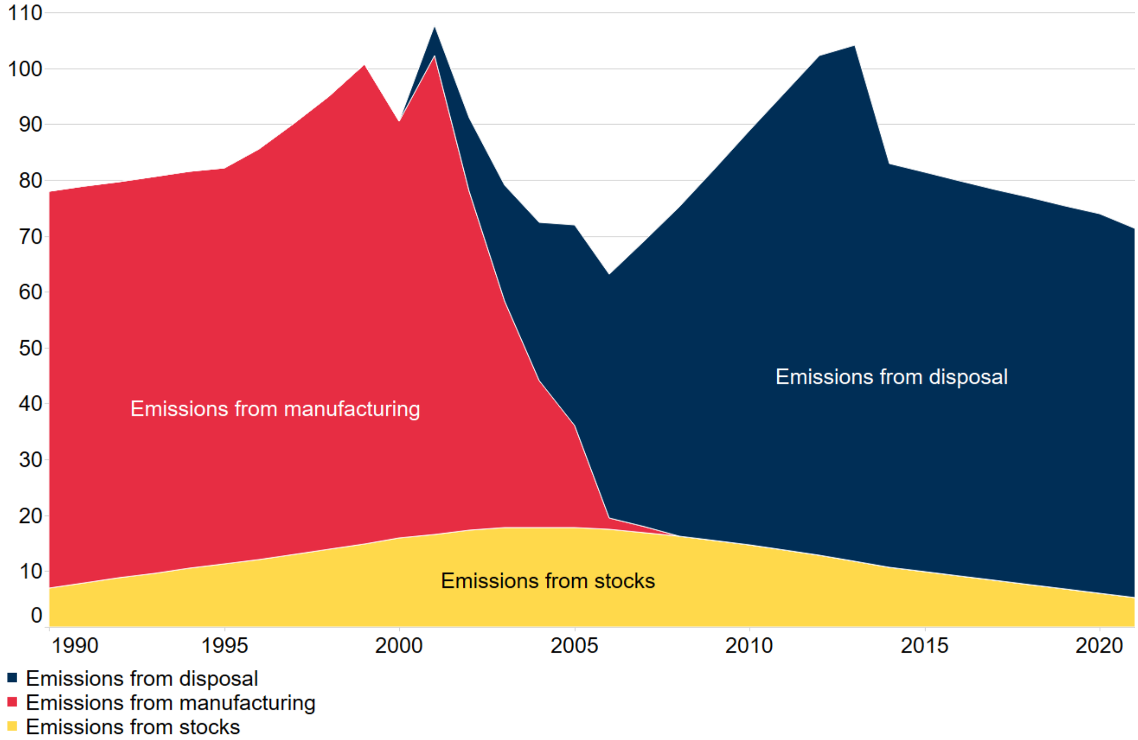
$$Leakage\ Emissions\ in\ year\ t = 0.01\ \times capacity\ of\ existing\ windows\ in\ year\ t$$

$$Disposal\ Emissions\ in\ year\ t = Amount\ left\ in\ Window\ at\ End\ of\ Lifetime\ in\ year\ t\ \times (1 - Recovery\ Factor)$$

Results

Since 2008, emissions from this sector only occur due to SF6 containing double glass that is replaced and decommissioned. The emissions in 2021 of SF6 from disposal were 72 kt CO_2-eq. It is estimated that by 2030 no further emissions will occur from this emission source.

Figure 4-31. Emissions of SF6 from soundproof windows in Belgium (in kt CO_2-eq).



Source: VITO, Econotec (own calculations, 2022).

4.10.3 Adiabatic properties: shoes (2.G.2.d.)

Introduction

One global sport brand (Nike) used SF6 and C3F8 in the gas cushioned sole of sport shoes. Nike started using SF6 in the early 1990s and started phasing this out in 1997 gradually. In some of the applications, SF6 was deemed not yet replaceable in that period, so it took until 2003 for Nike to stop using SF6 in sport shoes. In most cases, SF6 was replaced by nitrogen gas but between 2003 and 2006 also C3F8 was used.

Methodology

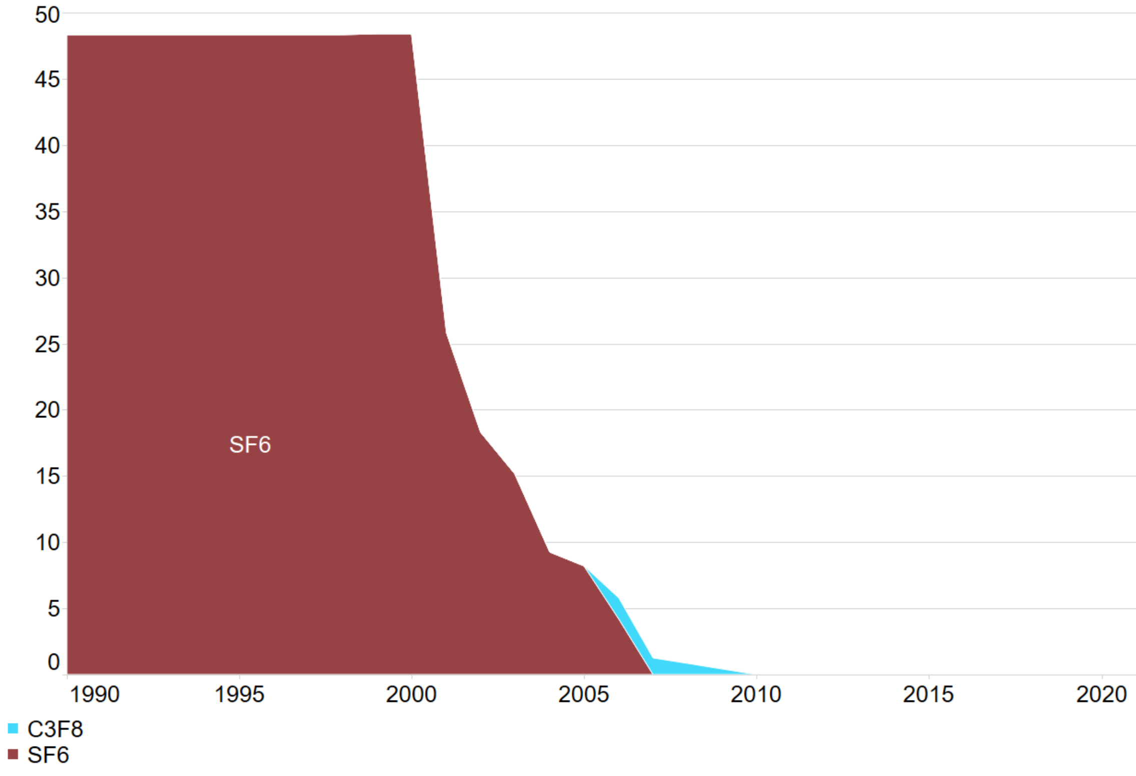
There was no production of these shoes in Belgium, so no manufacturing emissions are considered. We also assume that there are not operational emissions resulting from leakages in the gas cushioned sole. The lifetime of the shoes was estimated at 3 years, after which the entire quantity contained in the soles was considered to be emitted to the air during disposal.

For the calculation of the disposal emissions from this source, we used the methodology and assumptions also used by Schwarz [13]. Global data on SF6 use and data of the quantity of C3F8 placed on the EU market in sport soles are available. Schwarz assumes that 25% of the quantity of SF6 that was used to fill soles was sold in the EU. Based on the population, a part of this quantity was allocated to Belgium.

Results

The emissions are limited to the period 1996 – 2010. The highest annual SF6 emissions are estimated to be below 50 kt CO_2-eq.

Figure 4-32. Emissions of SF6 and C3F8 from shoes in Belgium (in kt CO_2-eq).



Source: VITO, Econotec (own calculations, 2022).

4.11 Ozone-depleting substances

Introduction

According to EC Regulation 2037/2000, the use of methyl bromide was prohibited since 1st January 2006, except for essential uses, critical uses for which a licence was awarded by the Commission, or for temporary emergency uses.

According to art. 4(2) of Commission Regulation 2032/2003, methyl bromide could not be placed on the market as biocidal product since 1st September 2006, and the use of methyl bromide for Quarantine & Preshipment (QPS) stopped in 2010.

The remaining emissions of methyl bromide are process emissions resulting from the manufacturing of purified terephthalate acid (PTA).

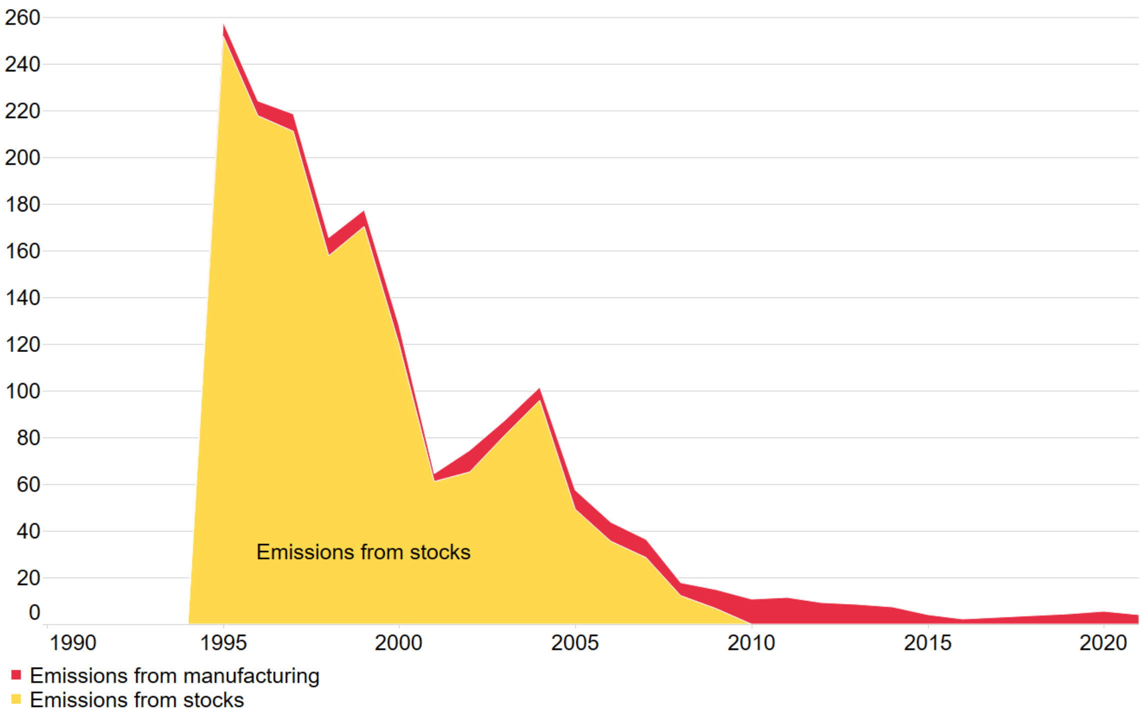
Methodology

The data for process emissions are those provided to the Vlaamse Milieumaatschappij by the company.

Results

The evolution of emissions is shown on Figure 4-33. In 2021 these emissions reached 3,93 t.

Figure 4-33. Emissions of methyl bromide in Belgium (in t).



Source: VITO, Econotec (own calculations, 2022).

4.12 Other substances

4.12.1 Sulfuryl fluoride

Sulfuryl fluoride (SO_2F_2) is used as a fumigant to replace methyl bromide that was phased out under the Montreal protocol. The IPCC's fifth assessment report GWP value for SO_2F_2 is 4090 and thus similar than the GWP value of CFC-11 and higher than the majority of HFCs.

At present there are few studies available that quantified SO_2F_2 emissions. Measurements on archived air samples and in situ observations from the Advanced Global Atmospheric Gases Experiment showed a global increase of the SO_2F_2 mole fraction from 0,3 to 2,5 ppt in the atmosphere, corresponding with a global increase in annual emissions from 0,5 to 2,9 Gg from 1978 to 2019. The global emissions increase is driven by the growing use of SO_2F_2 in structural fumigation in North America and in postharvest treatment of grains and other agricultural products worldwide [22]. Also in Australia, use and emissions of SO_2F_2 is driven by wheat production and wheat export [23]. SO_2F_2 emissions averaged about 350 kt CO_2-eq in 2012-2013, compared to 650 kt CO_2-eq for SF6 and 790 kt CO_2-eq for PFCs.

Estimated global production of SO_2F_2 was 3.000 t in 2011-2012 [23], assuming that all is emitted in the atmosphere, this amounts to an estimated global emission of 12.270 kt CO_2-eq.

Gressent et al. [24] estimated global and regional emissions between 2000-2019, based on a hybrid model incorporating bottom-up industry data and a top-down downscaling approach. Europe covered Italy, Switzerland, Germany, France, UK, Belgium, Greece, Spain, Ireland, Portugal, The Netherlands, Sweden, Austria, and Turkey. Emission in these European countries increased from 47 in 2003 (emissions in 2000-2002 were zero) to 255) to 255 t in 2019.

In Belgium SO_2F_2 is used as fumigants for imported food products (such as flour or cocoa), wood, furniture, etc. The most important users seem to be located in different ports but has also been used in the milling industry. The use of the gas has seen an important increase since 2005 and appears to be now one of the most important fumigants. The distributor of SO2F2 in Belgium informed us that 4 companies use SO_2F_2 as fumigant, for example EWS group, Decroes, and Anticimex.

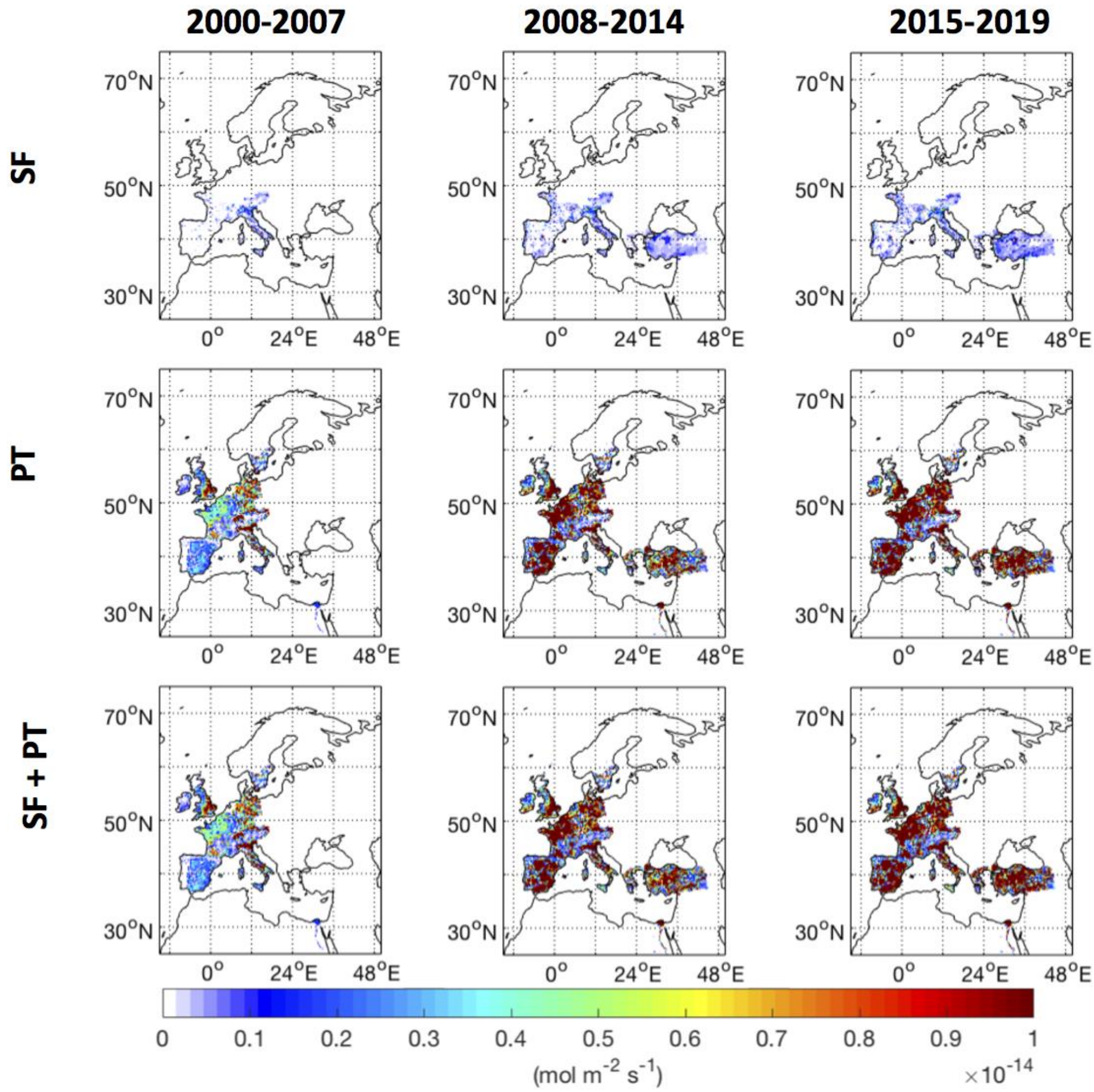
Table 4-24. Global emissions of SO2F2 between 2000 and 2019 (in t) [24]

Years	North America	Europe	Asia	Australia	Other countries	Total
2000	1.367,3	0,0	94,9	0,0	0,0	1.462,2
2001	1.422,1	0,0	95,4	0,0	0,0	1.517,5
2002	1.692,3	0,0	114,8	0,0	0,0	1.807,0
2003	1.857,5	47,0	136,1	0,0	0,0	2.040,6
2004	1.815,5	62,4	122,5	0,0	0,0	2.000,4
2005	1.949,8	75,2	139,3	0,0	0,0	2.164,2
2006	1.915,4	88,0	147,5	0,0	0,0	2.151,0
2007	1.453,2	148,0	107,3	0,0	2,3	1.710,8
2008	1.497,1	188,0	114,2	50,0	2,4	1.851,7
2009	1.615,6	154,6	160,3	66,6	2,7	1.999,8
2010	1.934,7	139,4	186,2	83,3	84,8	2.428,4
2011	1.950,6	152,2	206,5	100,0	94,6	2.503,8
2012	2.223,0	165,1	232,1	100,0	106,8	2.827,0
2013	2.452,0	177,8	253,7	100,0	117,4	3.101,0
2014	2.359,8	190,7	512,3	100,0	116,0	3.278,7
2015	2.397,5	203,5	499,7	100,0	113,5	3.314,2
2016	2.607,9	216,3	538,5	100,0	122,3	3.585,0
2017	2.735,6	229,2	540,7	100,0	122,8	3.728,3
2018	2.734,6	242,0	528,1	100,0	120,0	3.724,6
2019	2.799,1	254,8	537,1	100,0	122,0	3.813,0

Note: Europe covers Italy, Switzerland, Germany, France, UK, Belgium, Greece, Spain, Ireland, Portugal, The Netherlands, Sweden, Austria, and Turkey.

Source: Gressent et al. [24]

Figure 4-34. European SO2F2 emissions (2000-2007, 2008-2014, and 2015-2019, mol m^{-2} s^{-1}) from the downscaling approach at 0.352° × 0.234° horizontal resolution for structural fumigation (SF), post-harvest treatment (PT), and their sum (SF + PT) .



Source: Gressent et al. [24]

5 UNCERTAINTY ANALYSIS

5.1 Methodology

5.1.1 Introduction

The methodology used for the uncertainty analysis was described in detail in the update for 2004 (ECONOTEC & VITO, 2006). Therefore, it will only be summarised here.

This methodology follows the prescriptions of the *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2000), which itself relies on the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 1996).

It remains consistent with Approach 1 of the 2006 IPCC Guidelines (called Tier 1 in the Revised 1996 IPCC Guidelines). The new UNFCCC Guidelines specify that the Parties to the Convention must quantify uncertainty for all sources according to at least one approach, for at least the base year and the inventory year, and the uncertainty on the trend between the two years.

To this end, we have filled in as required Table 3.3 of Volume 1 of the 2006 IPCC Guidelines (IPCC, 2006), for the years 1995, 2012 and 2013.

As stated in (IPCC, 2000)[14], the greenhouse gas inventory is principally the sum of products of activity data and emission factors. In a simplified way[15]:

$$E_T = \Sigma E_i = \Sigma AV_i . EF_i,$$

where E_T is the total emission, AV is the activity variable, EF is the emission factor and i denotes each emission source category.

In order to evaluate the uncertainty on E, it is necessary, in a first step, to evaluate the uncertainty on the individual components AV_i and EF_i, and in a second step, to combine these uncertainties on the individual components.

As we shall see below, a peculiarity of F-gas emissions that makes the evaluation of emissions uncertainty trickier for these gases is the correlation between activity variables and emission factors.

5.1.2 Indicators of uncertainty

An uncertain parameter can be considered as a stochastic variable. Its uncertainty can be represented by a probability distribution, but it is more often expressed as uncertainty margins, which correspond to a confidence interval. The IPCC guidelines recommend,

[14] Page 6.12.

[15] In fact, the calculation is often more complicated, because emissions can depend on past activity variables. But it is generally possible to bring it down to the above formula, for example by representing an existing stock of fluid as an activity variable.

where data are sufficient, a confidence interval of 95% (IPCC, 2006, Vol. 1, p. 3.13), that is to say having a 95% probability of containing the true value.

In mathematical statistics, a parameter commonly used to express the uncertainty of a random variable is the standard deviation. The concept of standard deviation is useful for deriving relationships allowing to evaluate the uncertainty of combinations of random variables (see below), using error propagation equations.

The link between confidence interval and standard deviation depends on the type of probability distribution. Often a normal distribution is assumed for the variable under consideration; in this case, the confidence limits are symmetric about the mean and for a 95% confidence interval, the confidence limits are approximately 2 standard deviations of the variable, above and below the mean.

We represent these intervals by uncertainty margins expressed as percentage deviations from the mean.

In the case of the F-gas emissions, there is generally not enough statistical information available to establish probability distributions. Therefore, the uncertainty margins are based on expert judgement or on the literature.

5.1.3 Combination of uncertainties

Product of stochastic variables

In the case of a normal distribution, the uncertainty margin is proportional to the standard deviation of the distribution (and equal to 1,96 σ). Expressed relative to the mean, it is proportional to the coefficient of variation (CV = σ/m):

$$U = 1{,}96\ \sigma/m.$$

Therefore, if the emissions of source i can be calculated as:

$$E = AV.\ EF,$$

and the two variables are not correlated, then an approximate evaluation of the uncertainty on E is given by:

$$U_E = \pm\sqrt{U_{AV}{}^2 + U_{EF}{}^2} \qquad (1)$$

where U_{AV} and U_{EF} are the uncertainties on the activity variable and the emission factor, respectively. This equation is called ***Rule B*** in (IPCC, 2000).

However, this formula is only valid as long as $|U_{AV}|$ et $|U_{EF}|$ do not exceed 60%. In the case of F-gas emissions, this condition is not always met. A more general formula, which is valid without this restriction, provided the two variables are independent, is:

$$U_E = \pm\sqrt{U_{AV}{}^2 + U_{EF}{}^2 + \frac{1}{3{,}8} U_{AV}{}^2 \cdot U_{EF}{}^2} \qquad (2)$$

This formula is derived from that of the coefficient of variation of the product of two independent random variables X and Y (see e.g. (Dagnelie, 1992), p. 227):

$$CV_{XY} = \sqrt{CV_X^{\ 2} + CV_Y^{\ 2} + CV_X^{\ 2} \cdot CV_Y^{\ 2}}\ ,$$

Since CV = σ/m and U = 1,96 σ/m, one has indeed: CV = U/1,96.

Sum of stochastic variables

If the total emission of a gas is :

$$E = \Sigma E_i,$$

where E_i is the central estimate of the emission of the gas in source category i, and if the E_i variables are not correlated, then the uncertainty margin on E is :

$$U_E = \pm \frac{\sqrt{\Sigma\, U_{E,i}^{\ 2} \cdot C_i^{\ 2}}}{\sum C_i}\ , \qquad (3)$$

where $U_{E,i}$ is the overall percentage uncertainty for source category i of the gas.

This equation is equation 3.2 of (IPCC, 2006), volume 1, p. 3.28.

Approaches 1 and 2 of the IPCC

The 2006 IPCC Guidelines provide two approaches[16] for combining source category uncertainties into an uncertainty estimate for total national emissions :

Approach 1 consists in applying first IPCC *equation (1)* and afterwards equation (3). Hence it is based on simplifying assumptions (no correlation between variables and $|U_{AV}|$ et $|U_{EF}|$ below 60%). It calculates the uncertainty in terms of the standard deviation of the probability distribution, and hence cannot calculate asymmetric confidence intervals.

Approach 2 consists in applying a Monte Carlo simulation technique to calculate the probability distribution of the result. Its advantages is that it is generally applicable, as it can handle any sort of probability distributions, any size of uncertainty as well as correlation between the variables. However, it requires to know the probability distributions of the variables to be combined and the correlation between them, and are more complex to handle, given the number of emission sources and gases.

The data required for using Approach 2 (probability distributions and correlations) are generally not available, as there exist no statistical data allowing to estimate the parameters of the distributions. These parameters are therefore usually expert judgement estimates.

In general, the product of two variables with a normal distribution does not have a symmetrical distribution. Therefore, Approach 1 method does not always allow calculating the confidence intervals in a precise manner. However, there are several reasons why Approach 1 can be considered satisfactory:

- It provides the standard deviations (at least when the variables combined are uncorrelated), which are good indicators of the level of uncertainty even for asymmetric distributions.

16 These approaches used to be called Tier 1 and Tier 2 in the 1996 IPCC Guidelines.

- According to the central limit theorem[17], emission totals, which are sums of mostly independent variables, will tend to be normally distributed. Hence for these totals, it will often be enough to know the standard deviations.
- “An uncertainty analysis should be seen, first and foremost, as a means to help prioritise national efforts to reduce the uncertainty of inventories in the future, and guide decisions on methodological choice” ((IPCC, 2006), Volume 1, p. 3.6). For that purpose, it can be considered unnecessary to know precisely all the confidence intervals as long as the standard deviations are known, as well as the confidence intervals on the main emission totals.
- Finally, it should be remembered that the F-gases only represent a small fraction of total Kyoto greenhouse gas emissions (in the order of 3% in 1995, when they were at their highest level).

5.1.4 Method retained

For the emission inventory, it has been agreed by the steering group to use Approach 1, while enhancing it in two ways:

- by replacing formula (1) with formula (2), which is more accurate, in particular in the case of F-gases;
- by taking into account the correlation between activity variable and emission factor for the emission source categories where it is relevant.

Such a correlation exists in the case of cooling installations and insulation foams. Indeed, for these emission sources, the activity variable used (the stock of F-gas in equipment) is estimated as an analytical function of the emission factor (the average loss rate).

To take into account the correlation has consisted in carrying out sensitivity analyses on individual uncertain parameters, taking into account the analytical links between ‘activity variable’ and ‘emission factor’.

For each substance, only the emission sources for which the uncertainty is expected to influence the uncertainty of the overall emissions of the substance significantly, has been taken into account.

5.1.5 Trend uncertainties

As required by the IPCC, trend uncertainties are estimated using two sensitivities ((IPCC, 2006), Volume 1, pp 3.29-3.32):

Type A sensitivity: the change in the difference in overall emissions between the base year and the current year, expressed as a percentage, resulting from a 1% increase in emissions of a given source category and gas in both the base year and the current year.
Type B sensitivity: the change in the difference in overall emissions between the base year and the current year, expressed as a percentage, resulting from a 1% increase in emissions of a given source category and gas in the current year only.

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[17] This theorem states that the sum of a large number of independent random variables is approximately normally distributed, even though the random variables themselves may follow any distribution or be taken from different distributions. The only conditions are that the original random variables must have finite expectation and variance (the sum should not be dominated by one or a few components).

5.2 Results of the uncertainty analysis

As requested, the uncertainty evaluation has been carried out for the years 1990, 2020 (update) and 2021. The results are presented in tables in section 5.2.2.
These tables use the format of Table 6.1 of the IPCC Good Practice Guidance (IPCC, 2000), which is to be used for the official reporting.

The sources identified and their respective numbers are those of the Common Reporting Format of the National Emission Inventory.

The analysis by emission source of the data sources for uncertainty margins is presented in the update for 2004 (ECONOTEC & VITO, 2006).

It should be remembered that Tier 1 method uses symmetric deviations (proportional to standard deviations) as inputs. Therefore, when uncertainty margins on activity variables or emission factors are asymmetric, they are translated into symmetric deviations with an equivalent confidence interval.

Note that one type of uncertainty that is not taken into account in the Tier 1 calculation table is the underestimation arising because of sources that are unknown and hence not taken into account, e.g.:

- In the refrigeration, the foam and the fire extinguishing sectors, consumption data are obtained from a survey among consumers. While the data may be considered as accurate, it might be that unknown consumers or distributors have not been taken into account in the survey.
- It is also possible that some other applications have not been covered, especially if they concern small individual consumptions.

Overall, the results show for the F-gases an uncertainty of 0,7% of the total greenhouse gas emissions in 2021. The trend uncertainty is estimated at 0,5%.

Table 3.2: Approach 1 uncertainty calculation and reporting for year 1990

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC Source category	**Gas**	**Base year emissions (1990)**	**1990 emissions**	**Activity data uncertainty (%)**	**Emission factor uncertainty (%)**	**Combined uncertainty**	**Contribution to Variance by Category in 1990**	**Type A sensitivity**	**Type B sensitivity**	**Uncertainty in trend in national emissions introduced by emission factor uncertainty**	**Uncertainty in trend in national emissions introduced by activity data uncertainty**	**Uncertainty introduced into the trend in total national emissions**
		Gg CO2 eq	**Gg CO2 eq**									
		Input data	Input data	Input data	Input data	$\sqrt{E^2+F^2+\frac{1}{3,8}E^2.F^2}$	$\frac{(G*D)^2}{(\sum D)^2}$	Note B	$\frac{D}{\sum C}$	$I*F$	$J*E*\sqrt{2}$	$\sqrt{K^2+L^2}$
2 B 9 a By-product emissions	CF4	330,17	330,17	26%	0%	26%	0,0000%					
2 B 9 a By-product emissions	C2F6	611,35	611,35	26%	0%	26%	0,0001%					
2 B 9 a By-product emissions	C3F8	217,48	217,48	26%	0%	26%	0,0000%					
2 B 9 a By-product emissions	C4F10	237,37	237,37	26%	0%	26%	0,0000%					
2 B 9 a By-product emissions	C5F12	38,28	38,28	26%	0%	26%	0,0000%					
2 B 9 a By-product emissions	SF6	1.533,26	1.533,26	26%	0%	26%	0,0007%					
2 B 9 b Fugitive emissions	C4F10	26,38	26,38	26%	0%	26%	0,0000%					
2 B 9 b Fugitive emissions	C5F12	328,12	328,12	26%	0%	26%	0,0000%	**NOT RELEVANT FOR BASE YEAR**				
2 B 9 b Fugitive emissions	C6F14	245,62	245,62	26%	0%	26%	0,0000%					
2 G 1 Electrical equipment	SF6	6,81	6,81		50%	50%	0,0000%					
2 G 2 c Soundproof windows	SF6	78,00	78,00		100%	100%	0,0000%					
2 G 2 d Adiabatic properties: shoes	SF6	48,37	48,37		100%	100%	0,0000%					
Total F-gases		**3.701,21**	**3.701,21**				0,0010%					
Total 6 GHG (without LUCF)		**145.686,76**	**145.686,76**			Percentage uncertainty in total inventory	**0,321%**					

Note A: when only total uncertainty is known (not for emission factor and activity data separately), then :
- when uncertainty is correlated across years, the uncertainty is entered into column F, and 0 is entered in column E;
- when uncertainty is not correlated across years, the uncertainty is entered into column E, and 0 is entered in column F.

Note B: Entries in column I show how the difference in emissions between the base year and year t changes in response to a 1% increase in the emissions of source category x in the base year and year t.
This shows the sensitivity of the trend t in emissions to a systematic uncertainty in the emission estimate.

$$\frac{0{,}01\cdot D_x+\Sigma D_i-(0{,}01\cdot C_x+\Sigma C_i)}{(0{,}01\cdot C_x+\Sigma C_i)}\cdot 100-\frac{\Sigma D_i-\Sigma C_i}{\Sigma C_i}\cdot 100$$

Column J: Type B sensitivity shows how the difference in emissions between the base year and year t changes in response to a 1% increase of souce category x in emissions in year t only.

Table 3.2: Approach 1 uncertainty calculation and reporting for year 2020 - page 1

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC Source category	Gas	Base year emissions (1990)	2020 emissions	Activity data uncertainty (%)	Emission factor uncertainty (%)	Combined uncertainty	Contribution to Variance by Category in 2020	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Gg CO2 eq	Gg CO2 eq									
		Input data	Input data	Input data	Input data	$\sqrt{E^2+F^2+\frac{1}{3{,}8}E^2.F^2}$	$\frac{(G*D)^2}{(\sum D)^2}$	Note B	$\frac{D}{\sum C}$	$I*F$	$J*E*\sqrt{2}$	$\sqrt{K^2+L^2}$
2 B 9 a By-product emissions	CF4	330,17	55,13	26%	0%	26%	0,0000%	-0,001%	0,000%	0,00%	0,01%	0,014%
2 B 9 a By-product emissions	C2F6	611,35	0,00	26%	0%	26%	0,0000%	-0,003%	0,000%	0,00%	0,00%	0,000%
2 B 9 a By-product emissions	C3F8	217,48	0,00	26%	0%	26%	0,0000%	-0,001%	0,000%	0,00%	0,00%	0,000%
2 B 9 a By-product emissions	C4F10	237,37	0,00	26%	0%	26%	0,0000%	-0,001%	0,000%	0,00%	0,00%	0,000%
2 B 9 a By-product emissions	C5F12	38,28	0,00	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 B 9 a By-product emissions	SF6	1.533,26	0,00	26%	0%	26%	0,0000%	-0,008%	0,000%	0,00%	0,00%	0,000%
2 B 9 b Fugitive emissions	HFC-23	0,00	604,21	26%	0%	26%	0,0002%	0,004%	0,004%	0,00%	0,15%	0,152%
2 B 9 b Fugitive emissions	HFC-32	0,00	0,00	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 B 9 b Fugitive emissions	HFC-125	0,00	51,46	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,01%	0,013%
2 B 9 b Fugitive emissions	HFC-134	0,00	0,00	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 B 9 b Fugitive emissions	HFC-134a	0,00	0,13	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 B 9 b Fugitive emissions	HFC-143a	0,00	0,07	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 B 9 b Fugitive emissions	HFC-152a	0,00	0,00	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 B 9 b Fugitive emissions	HFC-227ea	0,00	17,90	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,005%
2 B 9 b Fugitive emissions	HFC-236fa	0,00	0,28	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 B 9 b Fugitive emissions	CF4	0,00	1,61	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 B 9 b Fugitive emissions	C2F6	0,00	7,23	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,002%
2 B 9 b Fugitive emissions	C3F8	0,00	17,15	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,004%
2 B 9 b Fugitive emissions	C4F10	26,38	66,88	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,02%	0,017%
2 B 9 b Fugitive emissions	C5F12	328,12	0,06	26%	0%	26%	0,0000%	-0,002%	0,000%	0,00%	0,00%	0,000%
2 B 9 b Fugitive emissions	C6F14	245,62	8,22	26%	0%	26%	0,0000%	-0,001%	0,000%	0,00%	0,00%	0,002%
2 B 9 b Fugitive emissions	SF6	0,00	2,76	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2 B 9 b Fugitive emissions	NF3	0,00	7,09	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,002%

Table 3.2 : Approach 1 uncertainty calculation and reporting for the year 2020 - page 2

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC Source category	Gas	Base year emissions (1990) Gg CO2 eq	2020 emissions	Activity data uncertainty (%)	Emission factor uncertainty (%)	Combined uncertainty	Contribution to Variance by Category in 2020	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data	Input data	$\sqrt{E^2+F^2+\frac{1}{3{,}8}E^2.F^2}$	$\frac{(G*D)^2}{(\sum D)^2}$	Note B	$\frac{D}{\sum C}$	$I*F$	$J*E*\sqrt{2}$	$\sqrt{K^2+L^2}$
2 E 1 Semiconductors	HFC-23	0,00	2,70		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,002%
2 E 1 Semiconductors	HFC-41	0,00	0,00		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 E 1 Semiconductors	CF4	0,00	15,00		100%	100%	0,0000%	0,000%	0,000%	0,01%	0,00%	0,010%
2 E 1 Semiconductors	C2F6	0,00	13,09		100%	100%	0,0000%	0,000%	0,000%	0,01%	0,00%	0,009%
2 E 1 Semiconductors	c-C4F8	0,00	0,41		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 E 1 Semiconductors	SF6	0,00	19,27		100%	100%	0,0000%	0,000%	0,000%	0,01%	0,00%	0,013%
2 E 1 Semiconductors	NF3	0,00	1,05		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2 E 4 Heat transfer fluid	HFC-125	0,00	0,14		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 F 1 a Commercial refrigeration	HFC-23	0,00	31,28		75%	75%	0,0000%	0,000%	0,000%	0,02%	0,00%	0,016%
2 F 1 a Commercial refrigeration	HFC-32	0,00	9,45		75%	75%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,005%
2 F 1 a Commercial refrigeration	HFC-125	0,00	475,78		75%	75%	0,0011%	0,003%	0,003%	0,24%	0,00%	0,245%
2 F 1 a Commercial refrigeration	HFC-134a	0,00	269,87		75%	75%	0,0004%	0,002%	0,002%	0,14%	0,00%	0,139%
2 F 1 a Commercial refrigeration	HFC-143a	0,00	650,33		75%	75%	0,0021%	0,004%	0,004%	0,33%	0,00%	0,335%
2 F 1 a Commercial refrigeration	HFC-152a	0,00	0,00		75%	75%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 F 1 a Commercial refrigeration	C3F8	0,00	0,03		75%	75%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 F 1 a Domestic refrigeration	HFC-134a	0,00	1,06		75%	75%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2 F 1 b Transport refrigeration	HFC-32	0,00	0,31	100%	50%	115%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 F 1 d Transport refrigeration	HFC-125	0,00	8,55	100%	50%	115%	0,0000%	0,000%	0,000%	0,00%	0,01%	0,009%
2 F 1 d Transport refrigeration	HFC-134a	0,00	1,93	100%	50%	115%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,002%
2 F 1 d Transport refrigeration	HFC-143a	0,00	11,49	100%	50%	115%	0,0000%	0,000%	0,000%	0,00%	0,01%	0,012%
2 F 1 d Mobile air-conditioning	HFC-32	0,00	0,22	100%	50%	115%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 F 1 e Mobile air-conditioning	HFC-125	0,00	1,13	100%	50%	115%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2 F 1 e Mobile air-conditioning	HFC-134a	0,00	340,55	100%	50%	115%	0,0013%	0,002%	0,002%	0,12%	0,33%	0,351%
2 F 1 e Stationary air-conditioning	HFC-32	0,00	71,40		75%	75%	0,0000%	0,000%	0,000%	0,04%	0,00%	0,037%
2 F 1 f Stationary air-conditioning	HFC-125	0,00	325,99		75%	75%	0,0005%	0,002%	0,002%	0,17%	0,00%	0,168%
2 F 1 f Stationary air-conditioning	HFC-134a	0,00	136,49		75%	75%	0,0001%	0,001%	0,001%	0,07%	0,00%	0,070%

Table 3.2: Approach 1 uncertainty calculation and reporting for year 2021 - page 1

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC Source category	**Gas**	**Base year emissions (1990)**	**2021 emissions**	**Activity data uncertainty (%)**	**Emission factor uncertainty (%)**	**Combined uncertainty**	**Contribution to Variance by Category in 2021**	**Type A sensitivity**	**Type B sensitivity**	**Uncertainty in trend in national emissions introduced by emission factor uncertainty**	**Uncertainty in trend in national emissions introduced by activity data uncertainty**	**Uncertainty introduced into the trend in total national emissions**
		Gg CO2 eq	**Gg CO2 eq**									
		Input data	Input data	Input data	Input data	$\sqrt{E^2+F^2+\frac{1}{3,8}E^2.F^2}$	$\frac{(G*D)^2}{(\sum D)^2}$	Note B	$\frac{D}{\sum C}$	$I*F$	$J*E*\sqrt{2}$	$\sqrt{K^2+L^2}$
2 B 9 a By-product emissions	CF4	330,17	75,51	26%	0%	26%	0,0000%	-0,001%	0,001%	0,00%	0,02%	0,019%
2 B 9 a By-product emissions	C2F6	611,35	0,00	26%	0%	26%	0,0000%	-0,003%	0,000%	0,00%	0,00%	0,000%
2 B 9 a By-product emissions	C3F8	217,48	0,00	26%	0%	26%	0,0000%	-0,001%	0,000%	0,00%	0,00%	0,000%
2 B 9 a By-product emissions	C4F10	237,37	0,00	26%	0%	26%	0,0000%	-0,001%	0,000%	0,00%	0,00%	0,000%
2 B 9 a By-product emissions	C5F12	38,28	0,00	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 B 9 a By-product emissions	SF6	1.533,26	0,00	26%	0%	26%	0,0000%	-0,008%	0,000%	0,00%	0,00%	0,000%
2 B 9 b Fugitive emissions	HFC-23	0,00	99,83	26%	0%	26%	0,0000%	0,001%	0,001%	0,00%	0,03%	0,025%
2 B 9 b Fugitive emissions	HFC-32	0,00	0,00	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 B 9 b Fugitive emissions	HFC-125	0,00	7,81	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,002%
2 B 9 b Fugitive emissions	HFC-134	0,00	0,00	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 B 9 b Fugitive emissions	HFC-134a	0,00	0,02	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 B 9 b Fugitive emissions	HFC-143a	0,00	0,03	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 B 9 b Fugitive emissions	HFC-152a	0,00	0,00	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 B 9 b Fugitive emissions	HFC-227ea	0,00	0,06	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 B 9 b Fugitive emissions	HFC-236fa	0,00	3,85	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2 B 9 b Fugitive emissions	CF4	0,00	1,19	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 B 9 b Fugitive emissions	C2F6	0,00	3,67	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2 B 9 b Fugitive emissions	C3F8	0,00	8,56	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,002%
2 B 9 b Fugitive emissions	C4F10	26,38	59,92	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,02%	0,015%
2 B 9 b Fugitive emissions	C5F12	328,12	0,03	26%	0%	26%	0,0000%	-0,002%	0,000%	0,00%	0,00%	0,000%
2 B 9 b Fugitive emissions	C6F14	245,62	8,59	26%	0%	26%	0,0000%	-0,001%	0,000%	0,00%	0,00%	0,002%
2 B 9 b Fugitive emissions	SF6	0,00	1,31	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 B 9 b Fugitive emissions	NF3	0,00	4,32	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%

Table 3.2 : Approach 1 uncertainty calculation and reporting for the year 2021 - page 2

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC Source category	Gas	Base year emissions (1990) Gg CO2 eq	2021 emissions	Activity data uncertainty (%)	Emission factor uncertainty (%)	Combined uncertainty	Contribution to Variance by Category in 2021	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data	Input data	$\sqrt{E^2+F^2+\frac{1}{38}E^2F^2}$	$\frac{(G*D)^2}{(\sum D)^2}$	Note B	$\frac{D}{\sum C}$	$I*F$	$J*E*\sqrt{2}$	$\sqrt{K^2+L^2}$
2 E 1 Semiconductors	HFC-23	0,00	1,95		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2 E 1 Semiconductors	HFC-32	0,00	0,00		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 E 1 Semiconductors	HFC-41	0,00	0,00		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 E 1 Semiconductors	CF4	0,00	12,75		100%	100%	0,0000%	0,000%	0,000%	0,01%	0,00%	0,009%
2 E 1 Semiconductors	C2F6	0,00	11,13		100%	100%	0,0000%	0,000%	0,000%	0,01%	0,00%	0,008%
2 E 1 Semiconductors	c-C4F8	0,00	0,52		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 E 1 Semiconductors	SF6	0,00	14,99		100%	100%	0,0000%	0,000%	0,000%	0,01%	0,00%	0,010%
2 E 1 Semiconductors	NF3	0,00	0,93		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2 E 4 Heat transfer fluid	HFC-125	0,00	0,14		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 F 1 a Commercial refrigeration	HFC-23	0,00	28,89		75%	75%	0,0000%	0,000%	0,000%	0,01%	0,00%	0,015%
2 F 1 a Commercial refrigeration	HFC-32	0,00	11,32		75%	75%	0,0000%	0,000%	0,000%	0,01%	0,00%	0,006%
2 F 1 a Commercial refrigeration	HFC-125	0,00	438,43		75%	75%	0,0010%	0,003%	0,003%	0,23%	0,00%	0,226%
2 F 1 a Commercial refrigeration	HFC-134a	0,00	245,80		75%	75%	0,0003%	0,002%	0,002%	0,13%	0,00%	0,127%
2 F 1 a Commercial refrigeration	HFC-143a	0,00	568,28		75%	75%	0,0016%	0,004%	0,004%	0,29%	0,00%	0,293%
2 F 1 a Commercial refrigeration	HFC-152a	0,00	0,00		75%	75%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 F 1 a Commercial refrigeration	C3F8	0,00	0,13		75%	75%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 F 1 a Domestic refrigeration	HFC-134a	0,00	1,45		75%	75%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2 F 1 b Transport refrigeration	HFC-32	0,00	0,28	100%	50%	115%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 F 1 d Transport refrigeration	HFC-125	0,00	7,18	100%	50%	115%	0,0000%	0,000%	0,000%	0,00%	0,01%	0,007%
2 F 1 d Transport refrigeration	HFC-134a	0,00	1,60	100%	50%	115%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,002%
2 F 1 d Transport refrigeration	HFC-143a	0,00	8,80	100%	50%	115%	0,0000%	0,000%	0,000%	0,00%	0,01%	0,009%
2 F 1 d Mobile air-conditioning	HFC-32	0,00	0,27	100%	50%	115%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 F 1 e Mobile air-conditioning	HFC-125	0,00	1,38	100%	50%	115%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2 F 1 e Mobile air-conditioning	HFC-134a	0,00	303,68	100%	50%	115%	0,0011%	0,002%	0,002%	0,10%	0,29%	0,313%
2 F 1 e Stationary air-conditioning	HFC-32	0,00	81,75		75%	75%	0,0000%	0,001%	0,001%	0,04%	0,00%	0,042%
2 F 1 f Stationary air-conditioning	HFC-125	0,00	357,08		75%	75%	0,0006%	0,002%	0,002%	0,18%	0,00%	0,184%
2 F 1 f Stationary air-conditioning	HFC-134a	0,00	127,22		75%	75%	0,0001%	0,001%	0,001%	0,07%	0,00%	0,065%

Table 3.2 : Approach 1 uncertainty calculation and reporting for the year 2021 - page 3

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC Source category	**Gas**	**Base year emissions (1990)** **Gg CO2 eq**	**2021 emissions**	**Activity data uncertainty (%)**	**Emission factor uncertainty (%)**	**Combined uncertainty**	**Contribution to Variance by Category in 2021**	**Type A sensitivity**	**Type B sensitivity**	**Uncertainty in trend in national emissions introduced by emission factor uncertainty**	**Uncertainty in trend in national emissions introduced by activity data uncertainty**	**Uncertainty introduced into the trend in total national emissions**
		Input data	Input data	Input data	Input data	$\sqrt{E^2+F^2+\frac{1}{38}E^2.F^2}$	$\frac{(G*D)^2}{(\sum D)^2}$	Note B	$\frac{D}{\sum C}$	$I*F$	$J*E*\sqrt{2}$	$\sqrt{K^2+L^2}$
2 F 2 a Closed cell foam	HFC-134a	0,00	19,46	15%	5%	16%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,003%
2 F 2 a Closed cell foam	HFC-152a	0,00	14,87	15%	5%	16%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,002%
2 F 2 a Closed cell foam	HFC-227ea	0,00	4,19	15%	5%	16%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2 F 2 a Closed cell foam	HFC-245fa	0,00	0,14	15%	5%	16%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 F 2 a Closed cell foam	HFC-365mfc	0,00	7,40	15%	5%	16%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2 F 3 Fire protection	HFC-125	0,00	0,65	10%	50%	51%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 F 3 Fire protection	HFC-227ea	0,00	8,95	10%	50%	51%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,003%
2 F 4 a Metered dose inhalers	HFC-134a	0,00	42,11	25%	50%	56%	0,0000%	0,000%	0,000%	0,01%	0,01%	0,018%
2 F 4 a Metered dose inhalers	HFC-227ea	0,00	1,77	25%	50%	56%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2 F 4 b Technical aerosols	HFC-134a	0,00	0,47		200%	200%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2 F 4 b Technical aerosols	HFC-152a	0,00	0,22		200%	200%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 G 1 Electrical equipment	SF6	6,81	8,16		50%	50%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2 G 2 c Soundproof windows	SF6	78,00	71,33		100%	100%	0,0000%	0,000%	0,000%	0,01%	0,00%	0,010%
2 G 2 d Adiabatic properties: shoes	SF6	48,37	0,00		100%	100%	0,0000%	0,000%	0,000%	-0,02%	0,00%	0,024%
Total F-gases		**3.701,21**	**2.680,35**				0,0047%					0,003%
Total 7 GHGs (without LUCF)		**145.686,76**	**106.433,26**	(2020)		Percentage uncertainty in total inventory	**0,689%**				Trend uncertainty	**0,541%**

Note A: when only total uncertainty is known (not for emission factor and activity data separately), then :
- when uncertainty is correlated across years, the uncertainty is entered into column F, and 0 is entered in column E;
- when uncertainty is not correlated across years, the uncertainty is entered into column E, and 0 is entered in column F.

Note B: Entries in column I show how the difference in emissions between the base year and year t changes in response to a 1% increase in the emissions of source category x in the base year and year t.
This shows the sensitivity of the trend t in emissions to a systematic uncertainty in the emission estimate.

$$\frac{0{,}01\cdot D_x+\Sigma D_i-(0{,}01\cdot C_x+\Sigma C_i)}{(0{,}01\cdot C_x+\Sigma C_i)}\cdot 100-\frac{\Sigma D_i-\Sigma C_i}{\Sigma C_i}\cdot 100$$

Column J: Type B sensitivity shows how the difference in emissions between the base year and year t changes in response to a 1% increase of souce category x in emissions in year t only.

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ANNEX A EMISSION TABLES

A.1 Emissions of F-gases by CRF sector in t

Table A-1. Emissions of F-gases by CRF sector in Belgium in 2021 (t).

	Fluorochemical production	Commercial refrigeration	Stationary air-conditioning	Mobile air-conditioning	Transport refrigeration	Fire protection	Solvents	Closed cell foam	Electrical equipment	Other	General total
ODS	**0,0**	**1,9**	**0,0**	**0,0**	**0,0**	**1,8**	**0,0**	**232,9**	**0,0**	**3,9**	**240,5**
CFC	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**96,9**	**0,0**	**0,0**	**96,9**
CFC-11	0,0	0,0	0,0	0,0	0,0	0,0	0,0	49,5	0,0	0,0	49,5
CFC-12	0,0	0,0	0,0	0,0	0,0	0,0	0,0	47,4	0,0	0,0	47,4
Other CFCs	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
HCFC	**0,0**	**1,9**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**136,0**	**0,0**	**0,0**	**137,9**
HCFC-22	0,0	1,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,7
HCFC-124	0,0	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1
HCFC-141b	0,0	0,0	0,0	0,0	0,0	0,0	0,0	9,6	0,0	0,0	9,6
HCFC-142b	0,0	0,1	0,0	0,0	0,0	0,0	0,0	126,4	0,0	0,0	126,5
Halons	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**1,8**	**0,0**	**0,0**	**0,0**	**0,0**	**1,8**
Halon 1211	0,0	0,0	0,0	0,0	0,0	0,1	0,0	0,0	0,0	0,0	0,1
Halon 1301	0,0	0,0	0,0	0,0	0,0	1,6	0,0	0,0	0,0	0,0	1,6
Other ODS	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**3,9**	**3,9**
MB	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	3,9	3,9
CTC	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
CRF	**31,8**	**464,8**	**331,3**	**234,4**	**5,7**	**2,9**	**0,0**	**133,3**	**0,3**	**42,9**	**1.247,5**
HFC	**11,0**	**464,8**	**331,3**	**234,4**	**5,7**	**2,9**	**0,0**	**133,3**	**0,0**	**36,2**	**1.219,7**
HFC-23	8,1	2,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,2	10,5
HFC-32	0,0	16,7	120,8	0,4	0,4	0,0	0,0	0,0	0,0	0,0	138,3
HFC-41	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
HFC-125	2,5	138,3	112,6	0,4	2,3	0,2	0,0	0,0	0,0	0,0	256,4
HFC-134	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
HFC-134a	0,0	189,1	97,9	233,6	1,2	0,0	0,0	15,0	0,0	33,9	570,6
HFC-143a	0,0	118,4	0,0	0,0	1,8	0,0	0,0	0,0	0,0	0,0	120,2
HFC-152a	0,0	0,0	0,0	0,0	0,0	0,0	0,0	107,7	0,0	1,6	109,3
HFC-227ea	0,0	0,0	0,0	0,0	0,0	2,7	0,0	1,2	0,0	0,5	4,5
HFC-236fa	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5
HFC-245fa	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,2	0,0	0,0	0,2
HFC-365mfc	0,0	0,0	0,0	0,0	0,0	0,0	0,0	9,2	0,0	0,0	9,2
PFC	**20,5**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**3,0**	**23,5**
CF4	11,6	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,9	13,5
C2F6	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,3
C3F8	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0
C4F10	6,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	6,5
C5F12	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
C6F14	1,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,1
c-C4F8	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,1
SF6	**0,1**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,3**	**3,7**	**4,1**
NF3	**0,3**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,1**	**0,3**
Other	**48,4**	**15,3**	**0,0**	**118,1**	**0,2**	**0,0**	**0,0**	**24,8**	**0,0**	**0,4**	**207,1**
HFO	**0,0**	**15,3**	**0,0**	**118,1**	**0,2**	**0,0**	**0,0**	**24,8**	**0,0**	**0,0**	**158,4**
HFO-1234yf	0,0	14,1	0,0	118,1	0,2	0,0	0,0	0,0	0,0	0,0	132,4
HFO-1234ze(E)	0,0	1,2	0,0	0,0	0,0	0,0	0,0	24,8	0,0	0,0	25,9
Other	**48,4**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,4**	**48,7**
General total	**80,2**	**482,0**	**331,3**	**352,6**	**5,9**	**4,7**	**0,0**	**391,0**	**0,3**	**47,2**	**1.695,1**

A.2 Emissions of F-gases by CRF sector in kt CO_2-eq

Table A-2. Emissions of F-gases by CRF sector in Belgium in 2021 (kt CO2-eq).

	Fluorochemical production	Commercial refrigeration	Stationary air-conditioning	Mobile air-conditioning	Transport refrigeration	Fire protection	Solvents	Closed cell foam	Electrical equipment	Other	General total
ODS	**0,0**	**3,4**	**0,0**	**0,0**	**0,0**	**-63,5**	**0,0**	**853,1**	**0,0**	**-4,9**	**788,0**
CFC	**0,0**	**0,1**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**575,8**	**0,0**	**0,0**	**575,9**
CFC-11	0,0	0,0	0,0	0,0	0,0	0,0	0,0	144,4	0,0	0,0	144,4
CFC-12	0,0	0,1	0,0	0,0	0,0	0,0	0,0	431,4	0,0	0,0	431,5
Other CFCs	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
HCFC	**0,0**	**3,3**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**277,2**	**0,0**	**0,0**	**280,6**
HCFC-22	0,0	3,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	3,1
HCFC-124	0,0	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1
HCFC-141b	0,0	0,0	0,0	0,0	0,0	0,0	0,0	5,8	0,0	0,0	5,8
HCFC-142b	0,0	0,1	0,0	0,0	0,0	0,0	0,0	271,5	0,0	0,0	271,6
Halons	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**-63,5**	**0,0**	**0,0**	**0,0**	**0,0**	**-63,5**
Halon 1211	0,0	0,0	0,0	0,0	0,0	-2,3	0,0	0,0	0,0	0,0	-2,3
Halon 1301	0,0	0,0	0,0	0,0	0,0	-61,3	0,0	0,0	0,0	0,0	-61,3
Other ODS	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**-4,9**	**-4,9**
MB	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	-4,9	-4,9
CTC	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
CRF	**274,7**	**1.292,8**	**566,0**	**305,3**	**17,9**	**9,6**	**0,0**	**46,1**	**8,2**	**159,8**	**2.680,3**
HFC	**111,6**	**1.292,7**	**566,0**	**305,3**	**17,9**	**9,6**	**0,0**	**46,1**	**0,0**	**48,1**	**2.397,3**
HFC-23	99,8	28,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,9	130,7
HFC-32	0,0	11,3	81,7	0,3	0,3	0,0	0,0	0,0	0,0	0,0	93,6
HFC-41	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
HFC-125	7,8	438,4	357,1	1,4	7,2	0,6	0,0	0,0	0,0	0,1	812,7
HFC-134	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
HFC-134a	0,0	245,8	127,2	303,7	1,6	0,0	0,0	19,5	0,0	44,0	741,8
HFC-143a	0,0	568,3	0,0	0,0	8,8	0,0	0,0	0,0	0,0	0,0	577,1
HFC-152a	0,0	0,0	0,0	0,0	0,0	0,0	0,0	14,9	0,0	0,2	15,1
HFC-227ea	0,1	0,0	0,0	0,0	0,0	8,9	0,0	4,2	0,0	1,8	15,0
HFC-236fa	3,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	3,9
HFC-245fa	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,0	0,0	0,1
HFC-365mfc	0,0	0,0	0,0	0,0	0,0	0,0	0,0	7,4	0,0	0,0	7,4
PFC	**157,5**	**0,1**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**24,4**	**182,0**
CF4	76,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	12,7	89,5
C2F6	3,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	11,1	14,8
C3F8	8,6	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	8,7
C4F10	59,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	59,9
C5F12	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
C6F14	8,6	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	8,6
c-C4F8	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5	0,5
SF6	**1,3**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**8,2**	**86,3**	**95,8**
NF3	**4,3**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,9**	**5,2**
Other	**388,4**	**0,0**	**0,0**	**0,1**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**3,7**	**392,2**
HFO	**0,0**	**0,0**	**0,0**	**0,1**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,1**
HFO-1234yf	0,0	0,0	0,0	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,1
HFO-1234ze(E)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Other	**388,4**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**3,7**	**392,1**
General total	**663,1**	**1.296,2**	**566,0**	**305,4**	**17,9**	**-53,9**	**0,0**	**899,2**	**8,2**	**158,6**	**3.860,6**

A.3 Emissions of F-gases by year and sector in t

Table A-3. Emissions of F-gases by CRF sectors in Belgium (t)

		1990	1995	2000	2005
2.B.9	**Fluorochemical production**	**450,8**	**655,9**	**124,0**	**126,2**
2.E.1	**Integrated circuit or semiconductor**	**0,0**	**0,0**	**0,0**	**1,5**
2.E.4	**Heat transfer fluids**	**0,0**	**0,0**	**0,0**	**0,0**
2.F.1	**Refrigeration and air-conditioning equipment**	**1.356,5**	**1.532,2**	**1.515,3**	**1.490,2**
2.F.1.a	Commercial refrigeration	1.216,2	1.163,2	992,6	929,6
2.F.1.b	Domestic refrigeration	0,0	47,3	45,2	30,4
2.F.1.d	Transport refrigeration	0,0	0,4	3,4	8,4
2.F.1.e	Mobile air-conditioning	12,6	36,6	80,8	168,7
2.F.1.f	Stationary air-conditioning	127,8	284,5	393,4	353,1
2.F.2	**Foam blowing agents**	**1.197,7**	**2.412,3**	**2.292,3**	**848,2**
2.F.2.a	Closed cell foam	1.197,7	2.412,3	2.292,3	848,2
2.F.3	**Fire protection**	**0,0**	**12,6**	**14,0**	**10,5**
2.F.4	**Aerosols**	**0,0**	**98,7**	**124,9**	**69,0**
2.F.4.a	Metered dose inhalers	0,0	69,4	66,4	32,3
2.F.4.b	Other aerosols (technical aerosols)	0,0	29,3	58,5	36,7
2.F.5	**Solvents**	**0,0**	**50,0**	**225,0**	**15,0**
2.G.1	**Electrical equipment**	**0,3**	**0,4**	**0,4**	**0,5**
2.G.2	**SF6 and PFCs from other product use**	**5,4**	**5,6**	**5,9**	**3,4**
2.G.2.c	Soundproof windows	3,3	3,5	3,8	3,1
2.G.2.d	Adiabatic properties: shoes and tyres	2,1	2,1	2,1	0,3
2.G.2.e	SF6 and PFCs from other product use	0,0	0,0	0,0	0,0
X.X.X	**Other**	**0,0**	**287,1**	**129,0**	**58,0**
X.X.X.X	CCl4	0,0	29,2	0,7	0,7
X.X.X.X	Methyl bromide	0,0	257,9	128,3	57,3
Total	**Total**	**3.010,7**	**5.054,7**	**4.430,8**	**2.622,6**

		2010	2015	2020	2021
2.B.9	**Fluorochemical production**	**124,0**	**178,4**	**146,2**	**80,2**
2.E.1	**Integrated circuit or semiconductor**	**1,1**	**1,1**	**4,6**	**3,8**
2.E.4	**Heat transfer fluids**	**0,7**	**1,0**	**0,3**	**0,4**
2.F.1	**Refrigeration and air-conditioning equipment**	**1.599,0**	**1.380,1**	**1.218,6**	**1.172,9**
2.F.1.a	Commercial refrigeration	916,0	708,8	528,1	482,0
2.F.1.b	Domestic refrigeration	1,7	1,8	0,8	1,1
2.F.1.d	Transport refrigeration	13,1	11,4	7,2	5,9
2.F.1.e	Mobile air-conditioning	283,5	323,6	369,3	352,6
2.F.1.f	Stationary air-conditioning	384,7	334,4	313,3	331,3
2.F.2	**Foam blowing agents**	**730,2**	**461,7**	**364,3**	**391,0**
2.F.2.a	Closed cell foam	730,2	461,7	364,3	391,0
2.F.3	**Fire protection**	**8,5**	**6,6**	**5,0**	**4,7**
2.F.4	**Aerosols**	**65,2**	**64,5**	**34,8**	**34,9**
2.F.4.a	Metered dose inhalers	32,4	33,7	32,8	32,9
2.F.4.b	Other aerosols (technical aerosols)	32,9	30,8	2,0	2,0
2.F.5	**Solvents**	**0,0**	**0,0**	**0,0**	**0,0**
2.G.1	**Electrical equipment**	**0,7**	**0,5**	**0,5**	**0,3**
2.G.2	**SF6 and PFCs from other product use**	**3,8**	**3,5**	**3,1**	**3,0**
2.G.2.c	Soundproof windows	3,8	3,5	3,1	3,0
2.G.2.d	Adiabatic properties: shoes and tyres	0,0	0,0	0,0	0,0
2.G.2.e	SF6 and PFCs from other product use	0,1	0,0	0,0	0,0
X.X.X	**Other**	**11,3**	**4,0**	**5,4**	**3,9**
X.X.X.X	CCl4	0,7	0,0	0,0	0,0
X.X.X.X	Methyl bromide	10,6	4,0	5,4	3,9
Total	**Total**	**2.544,6**	**2.101,4**	**1.782,8**	**1.695,1**

A.4 Emissions of CRF F-gases by year and sector in kt CO_2-eq

Table A-4. Emissions of CRF F-gases by CRF sectors in Belgium (kt CO_2-eq.)

		1990	1995	2000	2005
2.B.9	**Fluorochemical production**	**3.568,0**	**4.783,3**	**403,0**	**769,2**
2.E.1	**Integrated circuit or semiconductor**	**0,0**	**0,0**	**0,0**	**16,3**
2.E.4	**Heat transfer fluids**	**0,0**	**0,0**	**0,0**	**0,0**
2.F.1	**Refrigeration and air-conditioning equipment**	**0,0**	**86,7**	**773,2**	**1.527,3**
2.F.1.a	Commercial refrigeration	0,0	61,1	591,1	1.183,5
2.F.1.b	Domestic refrigeration	0,0	0,0	0,3	0,5
2.F.1.d	Transport refrigeration	0,0	1,5	10,5	26,3
2.F.1.e	Mobile air-conditioning	0,0	21,4	105,2	219,5
2.F.1.f	Stationary air-conditioning	0,0	2,6	66,0	97,4
2.F.2	**Foam blowing agents**	**0,0**	**324,4**	**246,2**	**115,7**
2.F.2.a	Closed cell foam	0,0	324,4	246,2	115,7
2.F.3	**Fire protection**	**0,0**	**0,6**	**5,1**	**12,8**
2.F.4	**Aerosols**	**0,0**	**37,7**	**64,5**	**81,9**
2.F.4.a	Metered dose inhalers	0,0	0,0	0,4	36,2
2.F.4.b	Other aerosols (technical aerosols)	0,0	37,7	64,1	45,8
2.F.5	**Solvents**	**0,0**	**0,0**	**0,0**	**0,0**
2.G.1	**Electrical equipment**	**6,8**	**8,3**	**9,9**	**11,5**
2.G.2	**SF6 and PFCs from other product use**	**126,4**	**130,6**	**138,9**	**80,2**
2.G.2.c	Soundproof windows	78,0	82,2	90,5	72,0
2.G.2.d	Adiabatic properties: shoes and tyres	48,4	48,4	48,4	8,2
2.G.2.e	SF6 and PFCs from other product use	0,0	0,0	0,0	0,0
X.X.X	**Other**	**0,0**	**0,0**	**0,0**	**0,0**
X.X.X.X	CCl4	0,0	0,0	0,0	0,0
X.X.X.X	Methyl bromide	0,0	0,0	0,0	0,0
Total	**Total**	**3.701,2**	**5.371,5**	**1.640,8**	**2.615,0**

		2010	2015	2020	2021
2.B.9	**Fluorochemical production**	**586,8**	**1.077,1**	**840,2**	**274,7**
2.E.1	**Integrated circuit or semiconductor**	**12,0**	**12,6**	**51,5**	**42,3**
2.E.4	**Heat transfer fluids**	**0,0**	**0,0**	**0,1**	**0,1**
2.F.1	**Refrigeration and air-conditioning equipment**	**2.308,3**	**2.682,4**	**2.335,9**	**2.183,5**
2.F.1.a	Commercial refrigeration	1.669,0	1.847,3	1.436,7	1.292,8
2.F.1.b	Domestic refrigeration	2,2	2,4	1,1	1,4
2.F.1.d	Transport refrigeration	40,9	36,4	22,3	17,9
2.F.1.e	Mobile air-conditioning	368,7	418,8	341,9	305,3
2.F.1.f	Stationary air-conditioning	227,5	377,6	533,9	566,0
2.F.2	**Foam blowing agents**	**119,3**	**69,0**	**44,1**	**46,1**
2.F.2.a	Closed cell foam	119,3	69,0	44,1	46,1
2.F.3	**Fire protection**	**14,4**	**13,5**	**10,7**	**9,6**
2.F.4	**Aerosols**	**74,0**	**82,5**	**44,5**	**44,6**
2.F.4.a	Metered dose inhalers	42,3	44,7	43,8	43,9
2.F.4.b	Other aerosols (technical aerosols)	31,7	37,8	0,7	0,7
2.F.5	**Solvents**	**0,0**	**0,0**	**0,0**	**0,0**
2.G.1	**Electrical equipment**	**16,3**	**10,9**	**11,3**	**8,2**
2.G.2	**SF6 and PFCs from other product use**	**89,3**	**81,3**	**73,9**	**71,3**
2.G.2.c	Soundproof windows	88,8	81,3	73,9	71,3
2.G.2.d	Adiabatic properties: shoes and tyres	0,0	0,0	0,0	0,0
2.G.2.e	SF6 and PFCs from other product use	0,4	0,0	0,0	0,0
X.X.X	**Other**	**0,0**	**0,0**	**0,0**	**0,0**
X.X.X.X	CCl4	0,0	0,0	0,0	0,0
X.X.X.X	Methyl bromide	0,0	0,0	0,0	0,0
Total	**Total**	**3.220,5**	**4.029,5**	**3.412,2**	**2.680,3**

ANNEX B GWP AND ODP VALUES

Gas	Group		GWP (AR4)	GWP (AR5)	GWP (AR6)	GWP	ODP
HFC-125	HFC	CRF	3500	3170	3740	3170	
HFC-134	HFC	CRF	1100	1120	1260	1120	
HFC-134a	HFC	CRF	1430	1300	1530	1300	
HFC-143	HFC	CRF	353	328	364	328	
HFC-143a	HFC	CRF	4470	4800	5810	4800	
HFC-152	HFC	CRF	53	16	21,5	16	
HFC-152a	HFC	CRF	124	138	164	138	
HFC-161	HFC	CRF	12	4	4,84	4	
HFC-227ea	HFC	CRF	3220	3350	3600	3350	
HFC-23	HFC	CRF	14800	12400	14600	12400	
HFC-236cb	HFC	CRF	1340	1210	1350	1210	
HFC-236ea	HFC	CRF	1370	1330	1500	1330	
HFC-236fa	HFC	CRF	9810	8060	8690	8060	
HFC-245ca	HFC	CRF	693	716	787	716	
HFC-245fa	HFC	CRF	1030	858	962	858	
HFC-32	HFC	CRF	675	677	771	677	
HFC-365mfc	HFC	CRF	794	804	914	804	
HFC-41	HFC	CRF	92	116	135	116	
HFC-43-10-MEE	HFC	CRF	1640	1650	1650	1650	
NF3	NF3	CRF	17200	16100	17400	16100	
C10F18	PFC	CRF	7500	7190	7480	7190	
C2F6	PFC	CRF	12200	11100	12400	11100	
C3F8	PFC	CRF	8830	8900	9290	8900	
C4F10	PFC	CRF	8860	9200	10000	9200	
C5F12	PFC	CRF	9160	8550	9220	8550	
C6F14	PFC	CRF	9300	7910	8620	7910	
c-C3F6	PFC	CRF	17340	9200	9200	9200	
c-C4F8	PFC	CRF	10300	9540	9540	9540	
CF4	PFC	CRF	7390	6630	7380	6630	
SF6	SF6	CRF	22800	23500	25200	23500	
CFC-11	CFC	ODS	4750	4660	5560	2920	1
CFC-113	CFC	ODS	6130	5820	6520	4370	0,8
CFC-114	CFC	ODS	14400	8590	9430	8516	1
CFC-115	CFC	ODS	7370	7670	9600	9377	0,6
CFC-12	CFC	ODS	10900	10200	11200	9100	1
CFC-13	CFC	ODS	14000	13900	16200	13900	1
Halon 1211	Halons	ODS	1890	1750	1930	-17070	3
Halon 1301	Halons	ODS	7140	6290	7200	-37300	10
Halon 2402	Halons	ODS	1640	1470	2170	-29830	6
HCFC-123	HCFC	ODS	77	79	90,4	53	0,02
HCFC-124	HCFC	ODS	609	527	597	551	0,022
HCFC-141b	HCFC	ODS	725	782	860	599	0,11
HCFC-142b	HCFC	ODS	2310	1980	2300	2148	0,065
HCFC-22	HCFC	ODS	1810	1760	1960	1862	0,055
HCFC-31	HCFC	ODS	79,4	79,4	79,4	79,4	0,02
CCL4	Other ODS	ODS	1800	1730	2200	90	1,1
MB	Other ODS	ODS	5	2	2,43	-1248	0,6
HCFO-1233ZD	HCFO	Other	5	5	3,88	3,88	
HFO-1234mzz	HFO	Other	2	2	2,08	2,08	
HFO-1234yf	HFO	Other	4	4	0,501	0,501	
HFO-1234ze	HFO	Other	6	6	1,37	1,37	
(C2F5)OF	Other	Other	10000	10000	10000	10000	
ANDERE_OFCS	Other	Other	8985	8985	8985	8985	

Gas	Group		GWP (AR4)	GWP (AR5)	GWP (AR6)	GWP	ODP
C3F7NF2	Other	Other	10000	10000	10000	10000	
C7F17N	Other	Other	10000	10000	10000	10000	
C8F16O	Other	Other	10000	10000	10000	9400	
C8F19N	Other	Other	10000	10000	10000	10000	
CF3CF2CH3	Other	Other	4620	4620	4620	4620	
CF3CF2CHF2	Other	Other	2640	2640	2640	2640	
CF3CH2CF3	Other	Other	9810	8060	8060	8060	
CF3CHFOCF3	Other	Other	3220	3350	3350	3350	
CF3COF	Other	Other	2000	2000	2000	2000	
CF3SF5	Other	Other	17400	17400	17400	17400	
CH2=CF2	Other	Other	1	1	1	1	
CHF2CF2CF2CF3	Other	Other	2360	2360	2360	2360	
COF2	Other	Other	2	2	2	2	
Dimethylether	Other	Other					
HFP	Other	Other	0,05	0,05	0,05	0,05	
HFP_dimeer	Other	Other	1	1	1	1	
HFP_trimeer	Other	Other	1	1	1	1	
LBA	Other	Other	8985	8985	8985	8985	
OPEN_RINGEN	Other	Other	10357	10357	10357	10357	
PBSF	Other	Other	2000	2000	2000	2000	
PEM	Other	Other	10000	10000	10000	10000	
PFPMIE	Other	Other	10300	9710	10300	10300	
PFS	Other	Other	2000	2000	2000	2000	
PIPM	Other	Other	10960	10960	10960	10960	
PMM	Other	Other	9509	9509	9509	9509	
PNPM	Other	Other	10960	10960	10960	10960	
PTBA	Other	Other	9073	9073	9073	9073	
PTPA	Other	Other	8896	8896	8896	8896	
SF5CF3	Other	Other	17700	17400	18500	17400	
SO2F2	Other	Other	4090	4090	4090	4090	
C7F16	PFC	Other	7820	7820	8410	8410	
C8F18	PFC	Other	8000	8000	8260	8260	

Note: The GWP values used throughout the report is the column in yellow, which combines GWP AR5 values for CRF gases and GWP values based on latest available evidence for non-CRF gases.

GWP: Global Warming Potential, ODP: Ozone Depleting Potential, AR4: Fourth Assessment Report of the IPCC, AR5: Fifth Assessment Report of the IPCC, AR6: Sixth Assessment Report of the IPCC.

For ozone depleting substances, the GWP values used are net GWPs taking into account the indirect greenhouse effect of these substances, evaluated as the average of two extreme values (when relevant data are available).

ANNEX C REFRIGERANT MIX COMPOSITION

ASHRAE Number	GWP AR4 (*)	GWP AR5 (*)	GWP AR6 (*)	R22 HCFC	R124 HCFC	R142b HCFC	R23 HFC	R32 HFC	R125 HFC	R134a HFC	R143a HFC	R152a HFC	R227ea HFC	R116 PFC	R218 PFC	R1234yf HFO	R1234ze HFO	CF3I	R290 Propane	R600 Butane	R600a Isobutane	R601 Pentane	R601a Isopentane	R744 CO2
R401A	1258	1260	1263	53,0%	34,0%							13,0%												
R402A	2845	2647	2989	38,0%					60,0%										2,0%					
R403B	4541	4569	4721	56,0%											39,0%				5,0%					
R404A	3922	3943	4728						44,0%	4,0%	52,0%													
R407A	2107	1923	2262					20,0%	40,0%	40,0%														
R407C	1774	1624	1908					23,0%	25,0%	52,0%														
R407F	1825	1674	1965					30,0%	30,0%	40,0%														
R407H	1495	1378	1615					32,5%	15,0%	52,5%														
R408A	3222	3351	3856	47,0%					7,0%		46,0%													
R409A	1670	1670	1670	60,0%	25,0%	15,0%																		
R410A	2088	1924	2256					50,0%	50,0%															
R413A	2053	1945	2183							88,0%					9,0%						3,0%			
R417A	2346	2127	2508						46,6%	50,0%											3,4%			
R421B	3190	2890	3409						85,0%	15,0%														
R422A	3143	2847	3359						85,1%	11,5%											3,4%			
R422D	2729	2473	2917						65,1%	31,5%											3,4%			
R423A	2280	2274	2513							52,5%			47,5%											
R424A	2440	2212	2608						50,5%	47,0%										1,0%	0,9%		0,6%	
R426A	1508	1371	1614						5,1%	93,0%										1,3%			0,6%	
R427A	2138	2024	2397					15,0%	25,0%	50,0%	10,0%													
R428A	3607	3417	4061						77,5%		20,0%								0,6%	1,9%				
R434A	3245	3075	3654						63,2%	16,0%	18,0%										2,8%			
R437A	1805	1639	1930						19,5%	78,5%											1,4%	0,6%		
R438A	2265	2059	2425					8,5%	45,0%	44,2%										1,7%			0,6%	
R442A	1888	1754	2042					31,0%	31,0%	30,0%		3,0%	5,0%											
R448A	1387	1273	1494					26,0%	26,0%	21,0%						20,0%	7,0%							
R449A	1397	1282	1504					24,3%	24,7%	25,7%						25,3%								
R450A	605	547	643							42,0%							58,0%							
R452A	2140	1945	2292					11,0%	59,0%							30,0%								
R452B	698	676	779					67,0%	7,0%							26,0%								
R453A	1765	1636	1905					20,0%	20,0%	53,8%			5,0%							0,6%			0,6%	
R454A	239	237	270					35,0%								65,0%								
R454B	466	467	531					68,9%								31,1%								
R454C	148	146	166					21,5%								78,5%								
R455A	148,2	146	166					21,5%								75,5%								3,0%
R466A	733	696	808					49,0%	11,5%									39,5%						
R507A	3985	3985	4775						50,0%		50,0%													
R508A	13214	11607	13258				39,0%							61,0%										
R508B	13396	11698	13412				46,0%							54,0%										
R513A	631,4	572	673							44,0%						56,0%								
R513B	596	540	635							41,5%						58,5%								
R515A	390	402	432										12,0%			88,0%								
R515B	293	299	322										8,9%				91,1%							

(*) except for non-CRF components, for which AR6 values are used

ANNEX D INTERNATIONAL TRADE IN F-GASES

For up to 2015, official statistics on external trade are only be available for a limited number of substances. From 2016, they provide figures for a number of HFC gases, individually or for mixtures; in parallel the detail by substance for CFCs has been dropped. Note that these statistics are not necessarily complete (for the EU internal trade, in the case of Belgium they cover only companies with at least 1.000.000 EUR in external trade), nor entirely reliable.

The figures are given in **Error! Reference source not found.**table.

One should be careful in interpreting the figures of such a table. Indeed, this table shows for example in the past imports of methylbromide that are much larger than the exports, leading to large apparent domestic consumption. The explanation is that Belgium is re-exporting most of the methylbromide as a packaged product which in the trade statistics appears not under methylbromide (custom No. 29033911), but under custom No. 38089190 (other insecticides).

One can notice that the apparent net consumption is sometimes small compared to the amounts of import and export, implying a relatively large uncertainty on this net consumption. This is the case of R134a, for which 73% of the import in 2021 is re-exported.

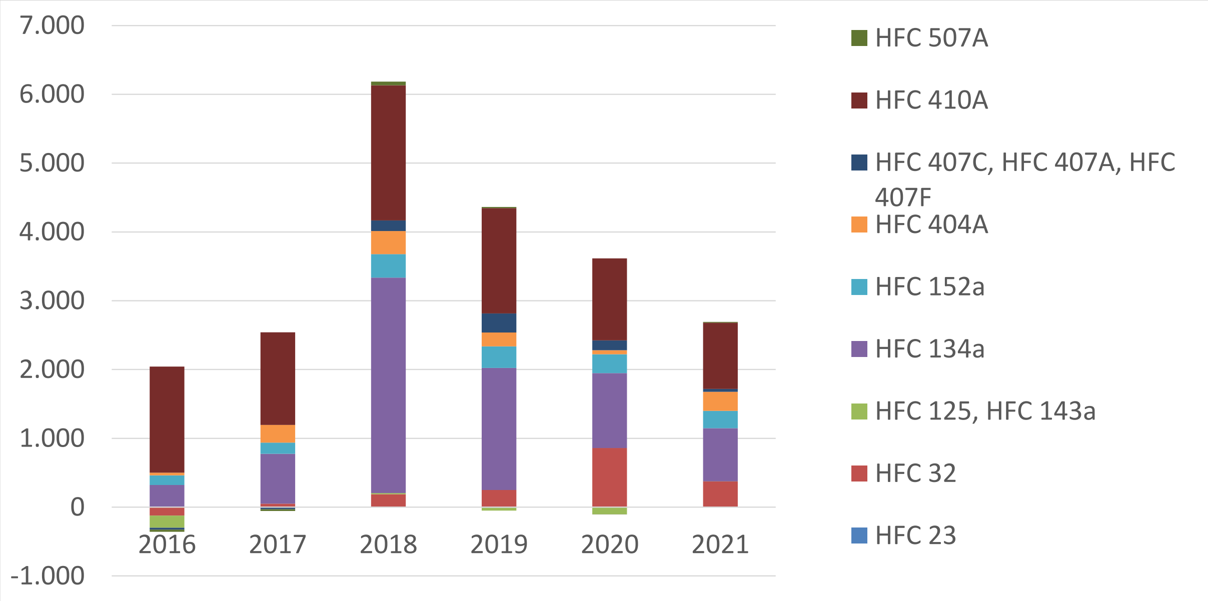
(tonnes)	Import 2010	2016	2017	2018	2019	2020	2021	Export 2010	2016	2017	2018	2019	2020	2021	Net Import 2010	2016	2017	2018	2019	2020	2021
CFC	**14,3**	**4,1**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,2**	**0,7**	**0,2**	**0,0**	**0,0**	**0,0**	**0,0**	**14,1**	**3,4**	**-0,2**	**0,0**	**0,0**	**0,0**	**0,0**
(CFC112)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
CFC 13	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
CFC 11	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
CFC 11 to 115	0,0	4,1	0,0	0,0	0,0	0,0	0,0	0,0	0,7	0,2	0,0	0,0	0,0	0,0	0,0	3,4	-0,2	0,0	0,0	0,0	0,0
CFC 111	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
CFC 113	13,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	13,2	0,0	0,0	0,0	0,0	0,0	0,0
CFC 114	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
CFC 115	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
CFC 12	1,1	0,0	0,0	0,0	0,0	0,0	0,0	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,9	0,0	0,0	0,0	0,0	0,0	0,0
HCFC	**4.701,9**	**2.014,6**	**1.077,3**	**508,0**	**538,7**	**78,1**	**2,6**	**4.763,1**	**1.770,5**	**1.128,7**	**1.031,2**	**541,6**	**302,4**	**17,2**	**-61,2**	**244,1**	**-51,4**	**-523,2**	**-2,9**	**-224,3**	**-14,6**
HCFC 123	0,0	0,0	0,0	36,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	36,9	0,0	0,0	0,0
HCFC 141	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	7,3	0,1	0,0	0,0	2,4	0,0	0,0	-7,3	-0,1	0,0	0,0	-2,3
HCFC 142	0,0	324,2	100,0	68,0	0,0	0,0	0,0	0,0	5,0	2,2	0,0	0,0	0,0	0,0	0,0	319,2	97,8	68,0	0,0	0,0	0,0
HCFC 22	4.701,9	1.690,4	977,3	403,1	538,7	78,1	2,5	4.763,1	1.765,5	1.119,2	1.031,1	541,6	302,4	14,8	-61,2	-75,1	-141,9	-628,0	-2,9	-224,3	-12,3
HCFC 225	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Halon	**0,2**	**0,0**	**0,0**	**0,0**	**0,0**	**0,1**	**0,1**	**22,6**	**2,0**	**0,0**	**6,8**	**0,0**	**0,0**	**0,0**	**-22,4**	**-2,0**	**0,0**	**-6,8**	**0,0**	**0,1**	**0,1**
halon 1211	0,2	0,0	0,0	0,0	0,0	0,0	0,0	16,1	2,0	0,0	0,0	0,0	0,0	0,0	-15,9	-2,0	0,0	0,0	0,0	0,0	0,0
halon 1301	0,0	0,0	0,0	0,0	0,0	0,0	0,0	6,5	0,0	0,0	6,8	0,0	0,0	0,0	-6,5	0,0	0,0	-6,8	0,0	0,0	0,0
halon 2402	0,0	0,0	0,0	0,0	0,0	0,1	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,1
CCl4	**2,8**	**0,1**	**0,0**	**0,0**	**0,0**	**0,0**	**1,3**	**0,1**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**2,7**	**0,1**	**0,0**	**0,0**	**0,0**	**0,0**	**1,3**
CCl4	2,8	0,1	0,0	0,0	0,0	0,0	1,3	0,1	0,0	0,0	0,0	0,0	0,0	0,0	2,7	0,1	0,0	0,0	0,0	0,0	1,3
TRE	**190,7**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**121,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**69,7**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**
1,1,1,-trichloroethane	190,7	0,0	0,0	0,0	0,0	0,0	0,0	121,0	0,0	0,0	0,0	0,0	0,0	0,0	69,7	0,0	0,0	0,0	0,0	0,0	0,0
Mebrom	**3.999,0**	**253,1**	**191,6**	**374,1**	**140,6**	**250,9**	**356,1**	**1.719,0**	**370,8**	**205,1**	**267,2**	**72,1**	**161,2**	**136,9**	**2.280,0**	**-117,7**	**-13,5**	**106,9**	**68,5**	**89,7**	**219,2**
methylbromide	3.999,0	253,1	191,6	374,1	140,6	250,9	356,1	1.719,0	370,8	205,1	267,2	72,1	161,2	136,9	2.280,0	-117,7	-13,5	106,9	68,5	89,7	219,2
HFC	**0,0**	**7.462,4**	**5.962,6**	**8.614,3**	**6.877,9**	**7.298,1**	**6.448,4**	**0,0**	**5.776,6**	**3.475,7**	**2.428,4**	**2.564,8**	**3.789,1**	**3.757,7**	**0,0**	**1.685,8**	**2.487,0**	**6.185,9**	**4.313,1**	**3.509,0**	**2.690,7**
HFC 23	0,0	9,2	4,7	3,3	5,0	1,3	0,9	0,0	3,0	2,3	0,4	13,3	1,1	2,9	0,0	6,2	2,4	2,9	-8,3	0,2	-2,0
HFC 32	0,0	2,4	67,9	240,4	294,1	1.374,9	1.247,4	0,0	126,5	19,0	54,4	45,2	514,7	872,9	0,0	-124,1	48,9	186,0	248,9	860,2	374,5
HFC 125, HFC 143a	0,0	0,0		21,5	11,8	8,4	0,9	0,0	174,7	1,3	6,3	54,9	111,5	0,0	0,0	-174,7	-1,3	15,2	-43,1	-103,1	0,9
HFC 134a	0,0	1.645,6	1.937,0	4.360,7	3.232,2	3.178,7	2.906,5	0,0	1.330,1	1.214,2	1.228,9	1.456,5	2.090,9	2.134,8	0,0	315,4	722,8	3.131,8	1.775,7	1.087,8	771,7
HFC 152a	0,0	151,3	189,2	343,6	314,0	275,4	253,3	0,0	11,0	25,7	1,7	0,8	0,6	1,1	0,0	140,2	163,5	341,8	313,2	274,8	252,2
HFC 404A	0,0	1.357,7	974,4	467,6	344,8	261,0	392,9	0,0	1.317,6	716,0	133,0	144,9	202,8	116,3	0,0	40,1	258,4	334,7	199,9	58,2	276,7
HFC 407C, HFC 407A, HFC 407F	0,0	555,0	372,1	525,3	541,5	417,4	253,2	0,0	583,4	402,8	371,7	263,6	274,8	210,2	0,0	-28,3	-30,7	153,6	277,9	142,6	43,0
HFC 410A	0,0	3.393,8	2.333,9	2.549,8	2.075,1	1.769,8	1.362,4	0,0	1.851,9	988,0	585,0	544,2	578,5	401,4	0,0	1.541,9	1.345,9	1.964,8	1.530,9	1.191,3	961,0
HFC 507A	0,0	347,5	83,4	102,1	59,4	11,2	30,9	0,0	378,5	106,2	47,0	41,4	14,2	18,2	0,0	-31,0	-22,8	55,1	18,0	-3,0	12,7
PFC	**0,0**	**187,8**	**246,7**	**115,4**	**93,5**	**341,3**	**438,3**	**0,0**	**39,6**	**33,4**	**15,9**	**8,8**	**16,9**	**12,6**	**0,0**	**148,2**	**213,3**	**99,5**	**84,7**	**324,4**	**425,8**
PFCs	0,0	187,8	246,7	115,4	93,5	341,3	438,3	0,0	39,6	33,4	15,9	8,8	16,9	12,6	0,0	148,2	213,3	99,5	84,7	324,4	425,8
HFO	**0,0**	**161,8**	**103,9**	**426,0**	**424,3**	**251,8**	**499,4**	**0,0**	**170,4**	**55,9**	**234,5**	**267,6**	**146,1**	**234,3**	**0,0**	**-8,6**	**48,0**	**191,5**	**156,7**	**105,7**	**265,1**
HFO 1234yf	0,0	90,7	23,5	82,2	101,7	47,7	82,3	0,0	126,8	9,0	12,3	41,9	13,4	20,6	0,0	-36,1	14,6	69,9	59,8	34,3	61,6
HFO 1234ze	0,0	71,0	80,3	343,8	322,6	204,1	417,1	0,0	43,6	46,9	222,2	225,7	132,7	213,6	0,0	27,5	33,4	121,6	96,9	71,4	203,5
Mixture	**0,0**	**117,7**	**75,5**	**42,1**	**45,5**	**23,3**	**23,2**	**0,0**	**53,0**	**36,6**	**15,6**	**4,2**	**5,5**	**2,0**	**0,0**	**64,7**	**38,9**	**26,5**	**41,3**	**17,8**	**21,2**
mixtures with CFC	0,0	47,2	27,8	35,5	44,7	22,8	21,9	0,0	0,6	0,6	0,1	0,1	0,1	0,1	0,0	46,7	27,2	35,3	44,6	22,7	21,8
mixtures with HCFC	0,0	70,5	47,7	6,6	0,8	0,5	1,3	0,0	52,4	36,0	15,5	4,1	5,4	1,9	0,0	18,1	11,7	-8,8	-3,3	-4,9	-0,6
mixtures with PFC/HFC	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Total	**8.908,9**	**10.201,6**	**7.657,6**	**10.080,0**	**8.120,5**	**8.243,6**	**7.769,4**	**6.626,0**	**8.183,6**	**4.935,6**	**3.999,6**	**3.459,1**	**4.421,2**	**4.160,6**	**2.282,9**	**2.018,0**	**2.722,0**	**6.080,3**	**4.661,4**	**3.822,4**	**3.608,9**

Source : Eurostat

n.a.: not available in the product nomenclature for the corresponding year

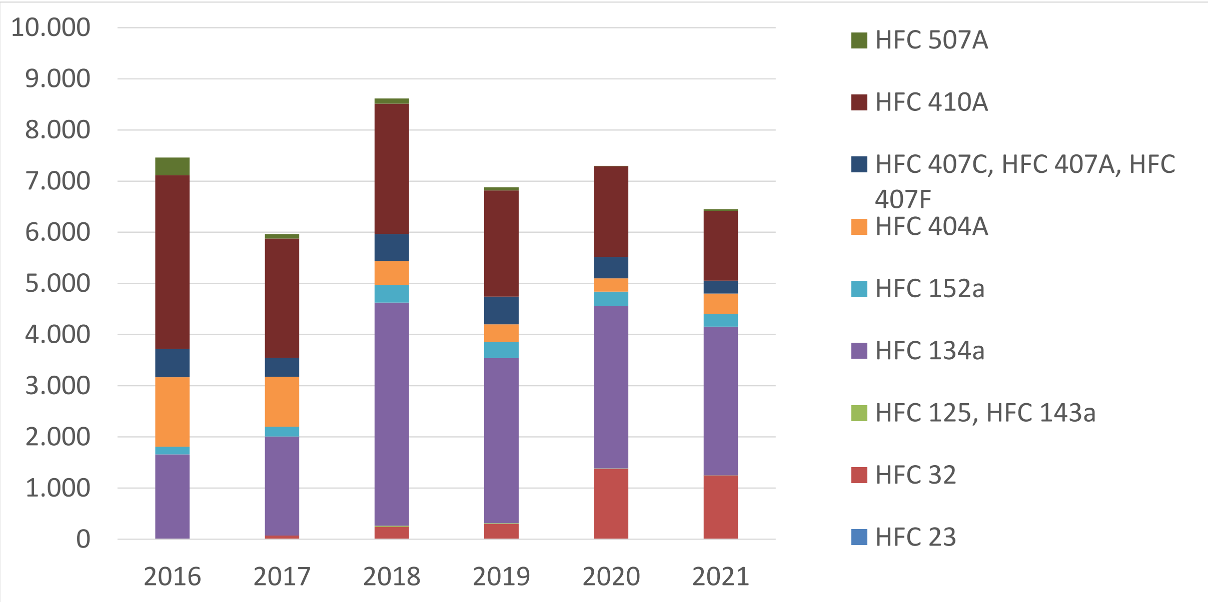
Net imports of HFCs sank again, by 23% in 2021 (Figure D-1). HFC-32 accounts for 59% of this decrease, caused mainly by a reduction in imports (Figure D-3, Figure D-2).

Figure D-1. Net import of HFCs (t)



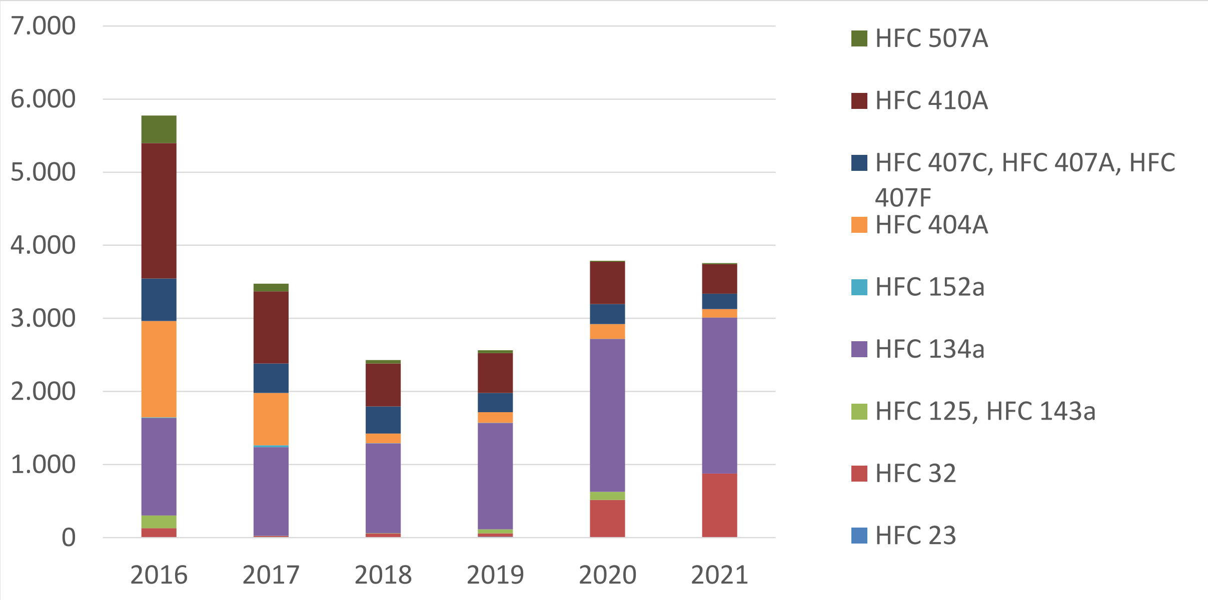
Source: Eurostat

Figure D-2. Import of HFCs (t)



Source: Eurostat

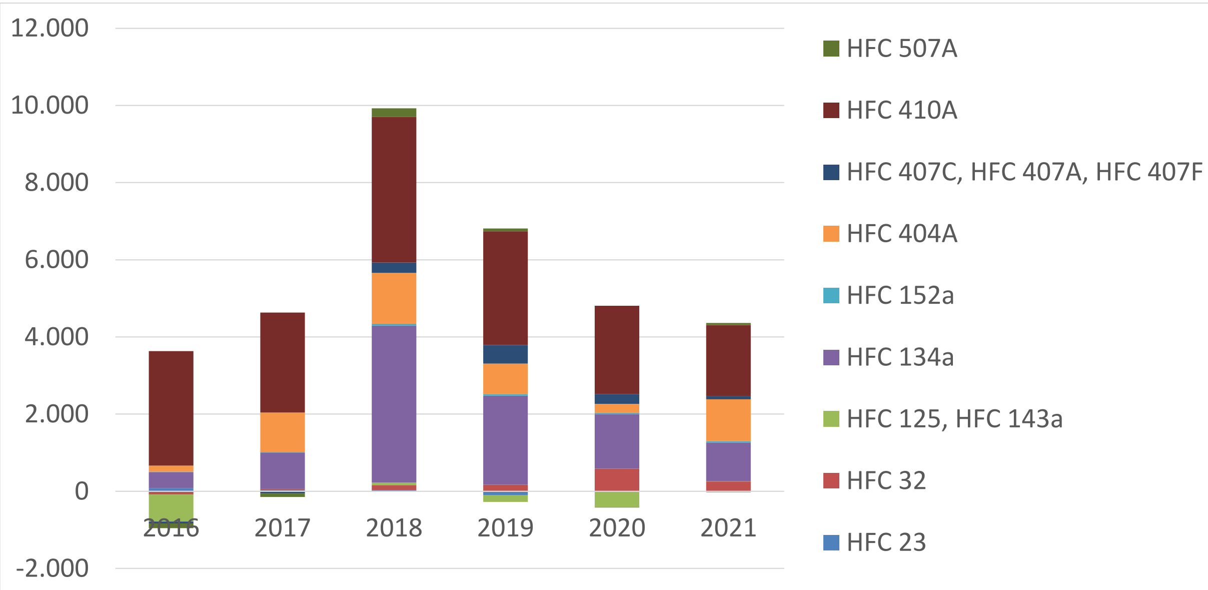
Figure D-3. Export of HFCs (t)



Source: Eurostat

In terms of CO_2-equivalents (using the GWPs of AR5)[18], the decrease in net imports is only 1%, because of the strong growth in net imports of R404A (+375%), with a high GDP value (3943).

Figure D-4. Net import of HFCs (kt CO2-eq)



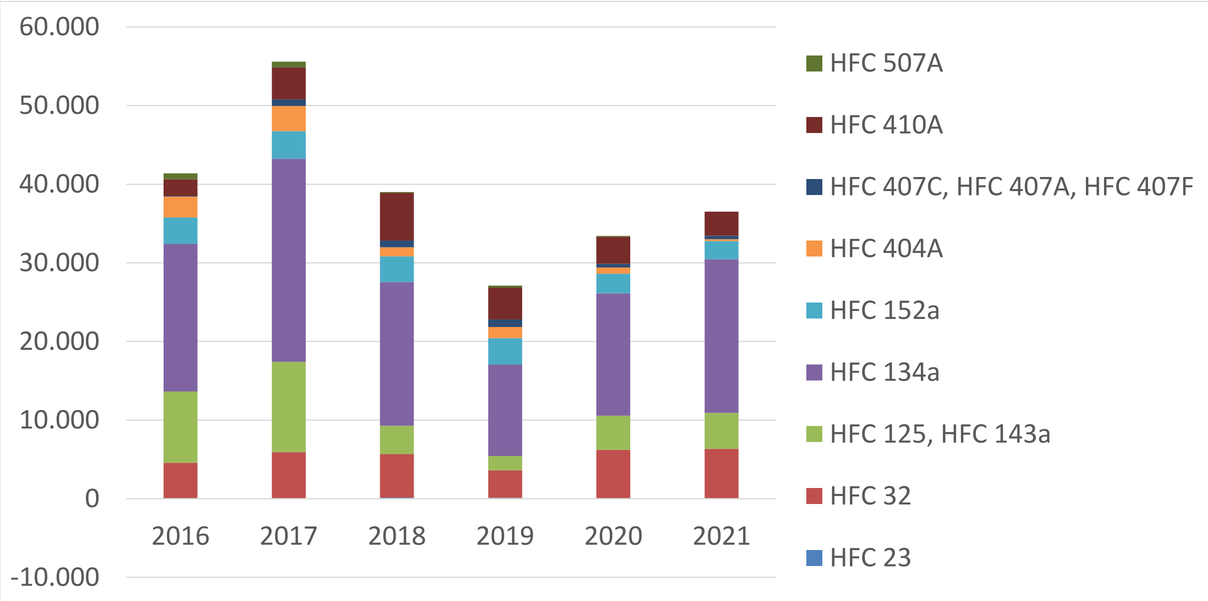
Source: Eurostat

18 A GWP value of 4000 has been assumed for 'HFC 125, HFC 143a' and 1740 for 'HFC 407C, HFC 407A, HFC 407F'.

The increase in 2018 is surprising, given the strong quota reduction at EU level in the framework of the Phase-Down scheme (Art. 15 of EU Regulation 517/2014).

This evolution differs from the one observed for the EU-27, as can be seen on Figure D-5 and Figure D-6[19], for which there is a rise in 2017, a strong decrease in 2018 and 2019, and an increase again in 2020 and 2021 (mainly of R410A).

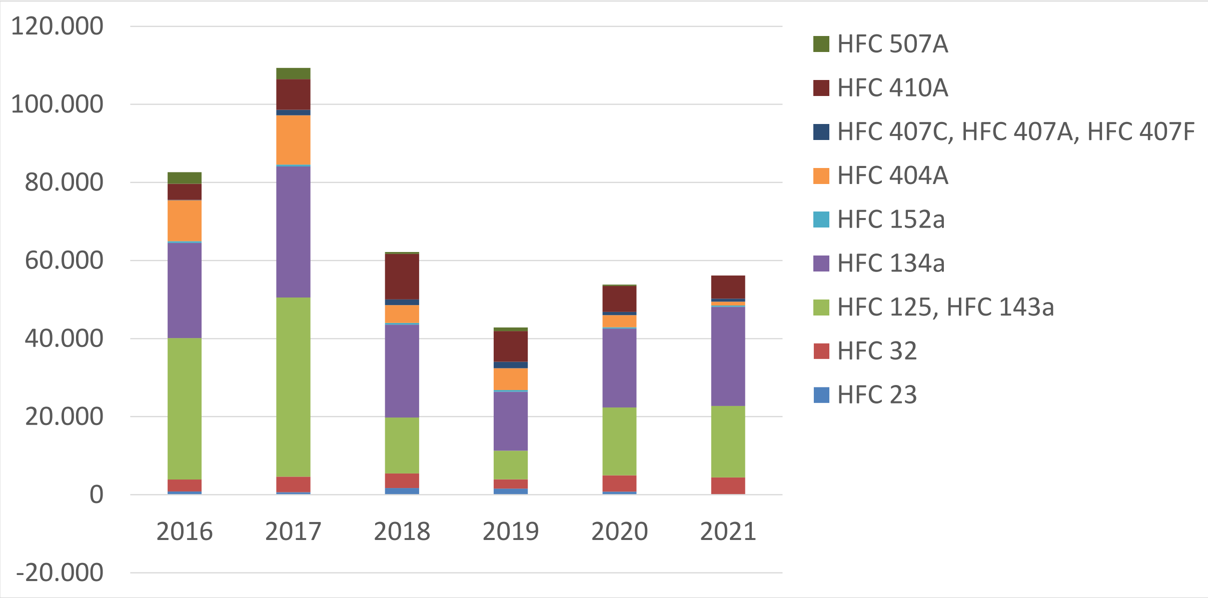
Figure D-5. Net import of HFCs in EU-27 (t)



Source: Eurostat

19 Figures for 2020 were not available yet at the time of preparation of this report.

Figure D-6. Net import of HFCs in EU-27 (kt CO_2-eq)



Source: Eurostat

ANNEX E LIST OF EMISSION SOURCES

Category used in calculation sheets	CRF Sector	
Chemical_industry_ducted	2.B.9.a	Fluorochemical production
Chemical_industry_non-ducted	2.B.9.b	Fluorochemical production
Heat_transfer_fluids	2.E.4.	Heat transfer fluids
Semiconductor	2.E.1.	Integrated circuit or semiconductor
Bus_Coach	2.F.1.e	Mobile air-conditioning
Cars	2.F.1.e	Mobile air-conditioning
Chillers	2.F.1.f	Stationary air-conditioning
Closed_foam	2.F.2.a	Closed cell foam
Commercial_refrigeration	2.F.1.a	Commercial refrigeration
Commercial_sealed	2.F.1.b	Domestic refrigeration
Domestic_refrigeration	2.F.1.b	Domestic refrigeration
Fire_extinguishers	2.F.3.	Fire protection
Foam_refrigeration	2.F.2.a	Closed cell foam
HP_boilers	2.F.1.f	Stationary air-conditioning
MDI	2.F.4.a	Metered dose inhalers
Movables	2.F.1.f	Stationary air-conditioning
Open_foam	2.F.2.a	Closed cell foam
Other_vehicles	2.F.1.e	Mobile air-conditioning
RAC_MIN_7	2.F.1.f	Stationary air-conditioning
RAC_PLUS_7	2.F.1.f	Stationary air-conditioning
Rail	2.F.1.e	Mobile air-conditioning
Refrigerated_transport	2.F.1.d	Transport refrigeration
Solvents	2.F.5.	Solvents
Technical_aerosols	2.F.4.b	Other aerosols (technical aerosols)
Tractors	2.F.1.e	Mobile air-conditioning
Trucks	2.F.1.e	Mobile air-conditioning
Tumble_dryers	2.F.1.f	Stationary air-conditioning
Chemical_industry_lab	2.G.2.e	SF6 and PFCs from other product use
Glass	2.G.2.c	Soundproof windows
Shoes	2.G.2.d	Adiabatic properties: shoes and tyres
Switchgear	2.G.1.	Electrical equipment
CCl4	X.X.X.x	CCl4
Methyl bromide	X.X.X.x	Methyl bromide

ANNEX F COMMON REPORTING FORMAT (CRF) NOMENCLATURE

NFR Code	CRF source category	Aggregate source
2 B	Chemical industry	
2 B 9	Fluorochemical production	Chemical industry
2 B 9 a	By-product emissions	Chemical industry
2 B 9 a 2	Other (please specify - one row per substance)	Chemical industry
2 B 9 b	Fugitive emissions	Chemical industry
2 B 9 b 3	Other (please specify - one row per substance)	Chemical industry
10	Other	
2 E	Electronics industry	
2 E 1	Integrated circuit or semiconductor	Electronics industry
2 E 2	TFT flat panel display	Electronics industry
2 E 3	Photovoltaics	Electronics industry
2 E 4	Heat transfer fluid	Electronics industry
2 E 5	Other (as specified in table 2(II))	Electronics industry
2 F	Product uses as substitutes for ODS	
2 F 1	Refrigeration and air conditioning	
2 F 1 a	Commercial refrigeration	Refrigeration & air conditioning
2 F 1 b	Domestic refrigeration	Refrigeration & air conditioning
2 F 1 c	Industrial refrigeration	Refrigeration & air conditioning
2 F 1 d	Transport refrigeration	Refrigeration & air conditioning
2 F 1 e	Mobile air-conditioning	Refrigeration & air conditioning
2 F 1 f	Stationary air-conditioning	Refrigeration & air conditioning
2 F 2	Foam blowing agents	Foams
2 F 2 a	Closed cell foam	Foams
2 F 2 b	Open cell foam	Foams
2 F 3	Fire protection	Fire protection
2 F 4	Aerosols	
2 F 4 a	Metered dose inhalers	Aerosols
2 F 4 b	Other aerosols (technical aerosols)	Aerosols
2 F 5	Solvents	Other
2 F 6	Other applications (ODS substitutes)	Other
2 G	Other product manufacture and use	
2 G 1	Electrical equipment	Other
2 G 2	SF6 and PFCs from other product use	
2 G 2 a	Military applications	Other
2 G 2 b	Accelerators	Other
2 G 2 c	Soundproof windows	Other
2 G 2 d	Adiabatic properties: shoes and tyres	Other
2 G 2 e	Other (please specify - one row per substance)	Other
2 G 4	Other	Other
2 H	Other	Other

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