

UPDATE OF THE NATIONAL EMISSION INVENTORY OF OZONE DEPLETING SUBSTANCES AND FLUORINATED GREENHOUSE GASES (1995-2018)

Final Report (rev.)

**Study commissioned by the Federal Public Service of Public Health, Food Chain Safety and Environment, on behalf of the National Climate Commission
(DG5/CC/AW/19.002)**

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1 EXECUTIVE SUMMARY

The present study has consisted in updating for the years 1995-2018 the Belgian emission inventory of ozone depleting substances and fluorinated greenhouse gases (F-gases) covered by both the Montreal Protocol and the Kyoto protocol.

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, 22 emission sources have been quantified, for 40 substances.

The emissions of the 4 F-gases under the Kyoto protocol, expressed in kt CO₂ equivalent, are shown on Figure 1 by gas and on Table 1 by source category.

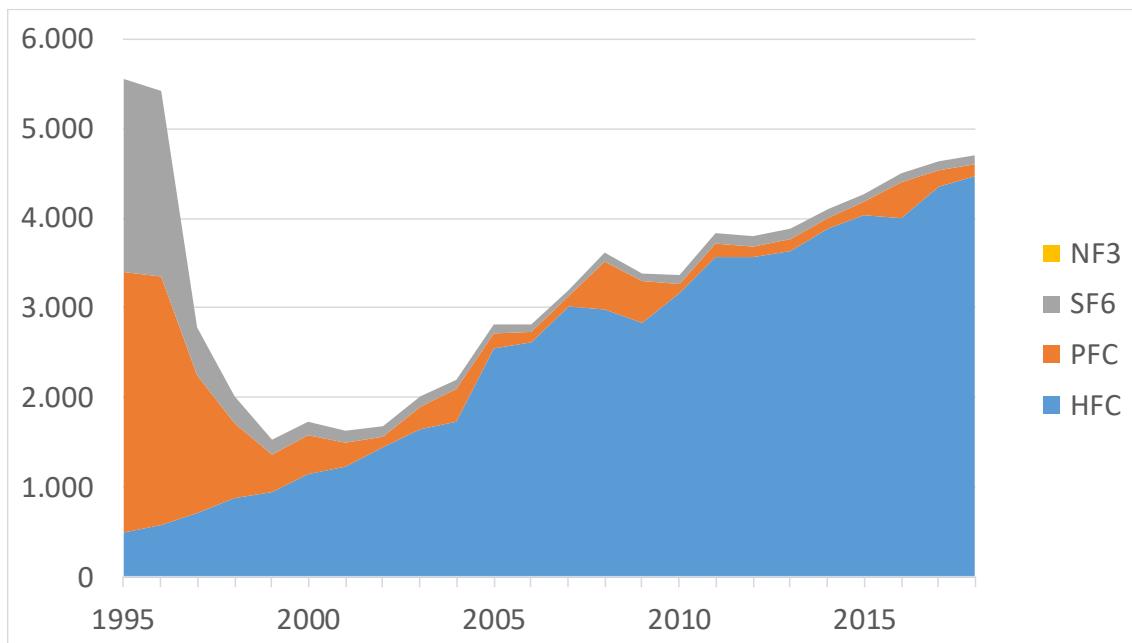


Figure 1: Evolution of the Kyoto F-gas emissions per gas category in Belgium (kt CO₂-eq)

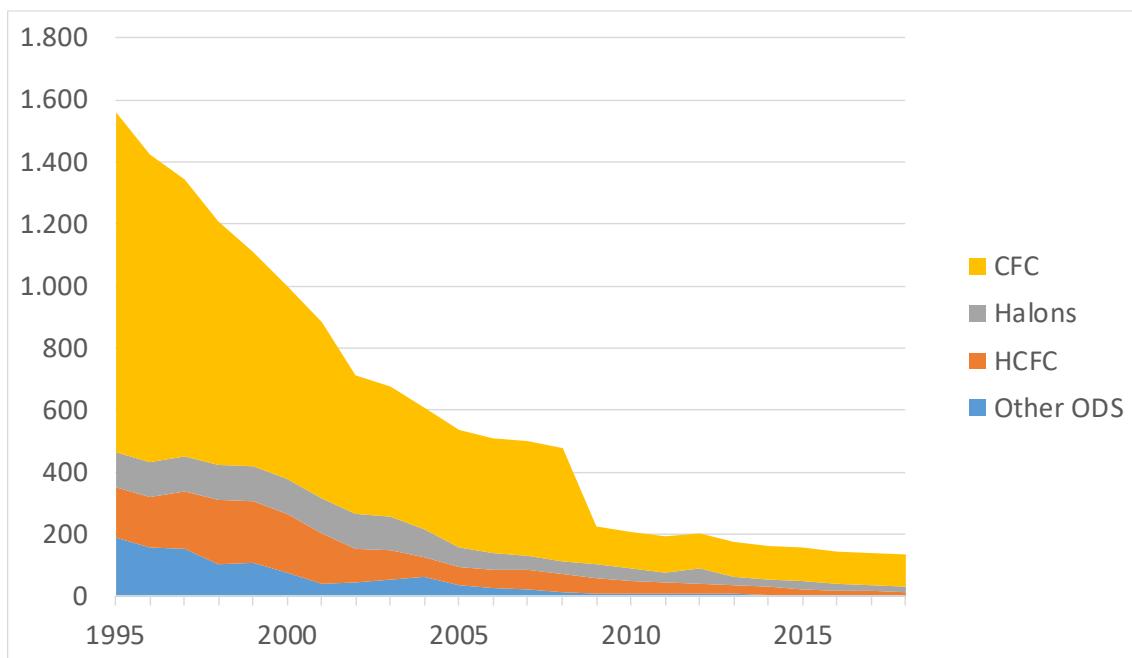
The overall emissions are steadily rising, though at a decreasing rate. By far the dominating contribution is that of hydrofluorocarbons (HFCs). The main emission sources are industrial and commercial refrigeration ('Commercial refrigeration'), fluorochemical production and mobile and stationary air conditioning.

In 2019 the emissions of fluorochemical production have been revised substantially upwards by the reporting company, based on an improved methodology. As a result, they now account for 37% of total emissions in 2018.

Table 1: Evolution of the Kyoto gas emissions by source, in kt CO₂-eq

(kt CO ₂ -eq)	1995	2000	2005	2010	2015	2016	2017	2018
01. Dom. refriger. - Coolant	0,1	2,6	23,1	18,7	23,6	21,4	20,4	19,1
02. Dom. refriger. - Foam	0,0	0,1	0,1	0,4	0,4	0,3	0,4	0,4
03. Stationary airco	1,8	45,9	67,8	165,5	320,2	351,2	393,3	350,5
04. Car airco	21,0	96,0	207,1	346,7	386,1	381,5	368,0	358,4
05. Bus&Coach airco	2,5	11,2	12,6	15,9	18,6	19,2	19,6	20,1
06. Trucks airco		6,8	22,3	45,4	63,4	67,6	69,6	69,4
07. Refrigerated transport	1,5	10,6	26,6	41,3	36,8	30,0	21,0	21,5
08. Passenger rail transport		3,7	3,8	4,6	3,0	3,3	3,4	4,0
10. Ind.&comm. refriger.	65,7	619,9	1.216,5	1.721,5	1.894,7	1.877,9	1.855,2	1.859,4
11. Closed cell foam		29,0	74,1	115,2	65,5	68,2	58,7	50,6
12. PU cans	356,8	239,0	48,0	3,8	4,9	23,6	28,1	3,1
13. Aerosols MDI		0,4	39,7	46,5	49,0	49,0	47,2	47,4
14. Other aerosols	41,5	70,3	50,3	34,6	41,5	45,1	35,7	32,7
17. SF6 electr. Sector	8,0	9,6	11,2	15,8	10,7	11,7	19,4	13,1
18. SF6 in glass sector	79,8	87,8	69,9	86,2	78,9	77,4	76,0	74,5
19. Fire Extinguishers	0,6	4,9	12,4	14,0	13,1	12,5	12,6	12,0
20. Chemical Ind	4.919,6	445,9	900,2	684,1	1.250,6	1.440,7	1.590,8	1.740,0
21. Semiconductors			17,8	13,0	13,6	21,1	19,0	20,7
22. Nike shoes	46,9	47,0	8,0					
Total	5.545,7	1.730,5	2.811,4	3.373,4	4.274,6	4.501,8	4.638,2	4.696,9

The emissions of ozone depleting substances (ODS) falling under the Montreal Protocol are shown on Figure 2, expressed in tonnes CFC-11 equivalent. The dominating gas category is the chlorofluorocarbons (CFC).

**Figure 2: Evolution of ozone depleting substances in Belgium (t CFC11-eq)**

As shown in Table 2, the dominant source of ODS gas emissions is insulation foam. These emissions essentially arise from the existing stock of insulation foam, as a result of the past consumption of these gases in foam manufacturing.

Table 2: Evolution of the emissions of ODS gases by source, in t CFC11-eq

(t CFC-11 eq)	1995	2000	2005	2010	2014	2016	2017	2018
01. Dom. refriger. - Coolant	47,30	44,98	29,96					
02. Dom. refriger. - Foam	286,07	282,04	210,65	0,00				
03. Stationary airco	14,03	17,68	15,23	13,60	8,28	4,63	3,06	0,95
04. Car airco	13,91							
05. Bus&Coach airco	6,29							
10. Ind.&comm. refriger.	547,93	123,55	30,83	16,67	4,74	2,11	0,81	0,46
11. Closed cell foam	268,51	250,53	145,27	130,51	120,83	116,36	114,21	112,11
13. Aerosols MDI	69,39	66,20	4,94	0,06				
15. CCl4	32,10	0,74	0,74	0,74	0,74			
16. Methylbr.	154,76	76,99	34,38	6,36	4,48	1,29	1,72	2,20
19. Fire Extinguishers	112,95	112,95	61,41	40,57	23,39	18,92	18,49	18,95
21. Semiconductors	0,00			0,00				
23. Solvents	5,50	24,75	1,65					
Total	1.558,74	1.000,42	535,07	208,51	162,47	143,31	138,29	134,67

2 INTRODUCTION

The present study has consisted in updating for the years 1995-2018 the Belgian emission inventory of ozone depleting substances and fluorinated greenhouse gases (F-gases).

For each year, the emissions are quantified by region, by emission source, by type of emission (manufacturing emissions, operating losses, disposal emissions...) and by individual substance.

This final report presents the work programme, the improvements made, the results obtained and the uncertainty analysis.

Please note that unless otherwise mentioned all tables and figures are given for Belgium as a whole.

3 WORK PROGRAMME

The inventory has been established according to the current UNFCCC guidelines [1], which are applicable since the 2015 submission of the national inventory (Decision 24/CP.19)¹. These guidelines implement the 2006 IPCC Guidelines [2].

In May 2019, the IPCC approved the “2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories”. This refinement still needs to be officially approved by the Conference of Parties of the UNFCCC. It will not replace the 2006 IPCC Guidelines. It is meant to be used in conjunction with the 2006 IPCC Guidelines.

3.1 Gases concerned

The inventory takes into account 50 gases:

- the 30 CRF-gases²;
- 12 ODS³ gases;
- 3 other PFCs, PFPMIE, CF3SF5 and 3 HFOs.

as well as an ‘unspecified mix’ used for the chemical industry. Out of these 51 substances, 40 have non-zero emission values.

¹ FCCC/CP/2013/Add.3.

² In this report, ‘CRF gases’ or ‘Kyoto-gases’ designates the compulsory gases of the UNFCCC reporting (19 HFCs, 9 PFCs, SF6 and NF3) in the framework of the Kyoto Protocol, which is to be carried out in the Common Reporting Format (CRF).

³ ODS: ozone depleting substances.

3.2 Global Warming Potential values (GWP)

In accordance with the / CP.19 Decision 24 of COP 2, the GWP values used for the CRF-gases are those listed in Annex III of this decision, which are those contained in the errata of contribution of WG1 to the Fourth Assessment Report of the IPCC [3].

For the remaining substances, the best available data have been used, among which those of the Fifth Assessment Report of the IPCC [4].

3.3 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 [5] 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 2018. Where improvements have been made to the methodology or to emission factors, or if a new source is added, recalculations have been made.

The following tasks have been carried out:

1. Data collection, among which:
 - enquiry among the refrigerant suppliers
 - enquiry among manufacturers of products containing F-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 F-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 2018
 - Update and optimisation of the emission estimates for the period 1995-2017
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 2018, as well as update of the uncertainty analyses for 1995 and 2017
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 F-gases for the National Inventory Report (methodology, information sources, recalculations made, uncertainty analysis, trend analysis)

3.4 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, number of private cars, greenhouse surface area.

4 IMPROVEMENTS

4.1 Improvements

The following improvements were made:

- A first analysis of the external trade statistics for HFCs for the period 2016-2018,
- Improvement of the evaluation of the emissions from chillers and adaptation of the consumption of industrial and commercial installations as a result,
- Improved modelling of the retrofit of R22, R404A and R507, and its impact on disposal emissions,
- Revised emission data for the emissions from fluorochemical production,
- Ad hoc changes after contacts with companies.

4.2 Recalculations for 1995-2017

The recalculations that have occurred compared with the 2019 submission of the inventory to UNFCCC are listed in the table below.

Table 3: Recalculations for 1995-2017 (CRF source categories)

CRF code	CRF source category	Period	Nature of the recalculation	Impact for CRF gases in 2017 (kt CO2-eq)
2 B 9	Fluorochemical production	2010-2017	Revised emission data from one company	+1435,5
2 E 1	Integrated circuit or semiconductor	2012-2017	Revised emission factor for one producer	+0,6
2 F 1 a	Commercial refrigeration	1995-2017	Compensation for changes in mobile air conditioning and R22 use in stationary air conditioning Improved calculation of retrofitting R22, R404A and R507 installations	+147,7
2 F 1 b	Domestic refrigeration	1996-2017	Extension of hermetically sealed cooling (previously only concerning supermarkets) to small shops, hotels and restaurants	+17,9
2 F 1 e	Mobile air-conditioning	1995-2017	Revised formula for the bank of bus & coach airco Revised assumptions on stock for bus & coaches and Trucks	-32,4
2 F 4 a	Metered dose inhalers	2008-2017	New data for 2014-2017; small correction for 2008-2013	-2,1
2 F 4 b	Other aerosols (technical aerosols)	2015-2017	Adaptation of German data used as reference	-3,6
2 G 1	Electrical equipment	1995-2017	Small correction in SF6 bank	+8,9
Total				+1572,5

Details on these recalculations are provided in chapter 6.

5 EXTERNAL TRADE IN F-GASES

5.1 Trade statistics

Official statistics on external trade are only available for a limited number of products. And they are not necessarily complete (for the EU internal trade, they cover only companies with at least 250.000 EUR in external trade), nor entirely reliable. From 2016, however, they at last provide figures for a number of HFC gases, individually or for mixtures; in parallel the detail by substance for CFCs has been dropped.

From 2016, bulk import and export figures are available for the following 12 new product categories:

- HFC 32,
- HFC 23,
- HFC 125 & HFC 143a,
- HFC 152a,
- HFC 134a,
- PFCs,
- HFO 1234yf,
- HFO 123ze,
- HFC 507A,
- HFC 404A,
- HFC 410A,
- HFC 407C, HFC 407A and HFC 407F.

The figures are given in Table 4. Note that the figures for 2015 and 2016 have been revised, as it is each year the case with the data of the previous year.

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. 29033033), but under custom No. 38081090 (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 R22, for which there is still a large trade, although there is an EU ban on putting this substance on the market since 1st January 2015 (HCFCs are still allowed in developing countries). R22 is mainly imported from the Netherlands and mainly exported to the United Arab Emirates, Saudi Arabia, Iraq and Pakistan.

The large net import of R404A in 2017 could be explained by growing stocks, given the rapidly increasing prices in the second half of the year. However, for R507A, a very similar refrigerant, the net import is negative.

Net imports of HFCs grow by a factor of 3,7 from 2016 to 2018 (Figure 3). The increase is essentially that of HFC-134a and HFC-410A. While in the case of HFC-134a it can mainly explained by an increase in imports (Figure 4), in the case of HFC-410A it mainly results from a strong decline in exports (Figure 5).

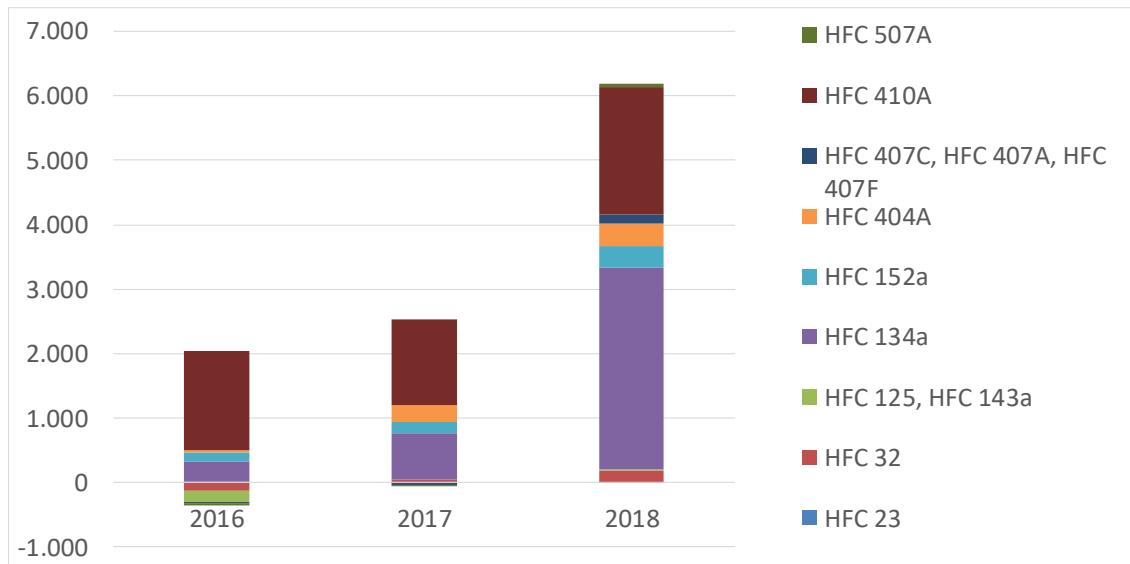


Figure 3: Net import of HFCs (t)

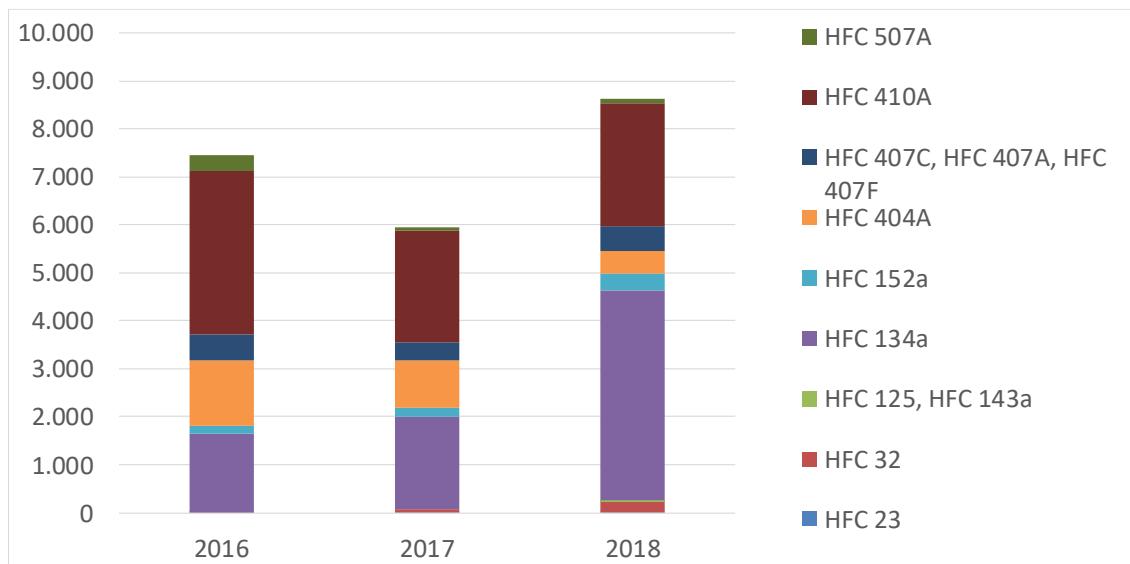


Figure 4: Import of HFCs (t)

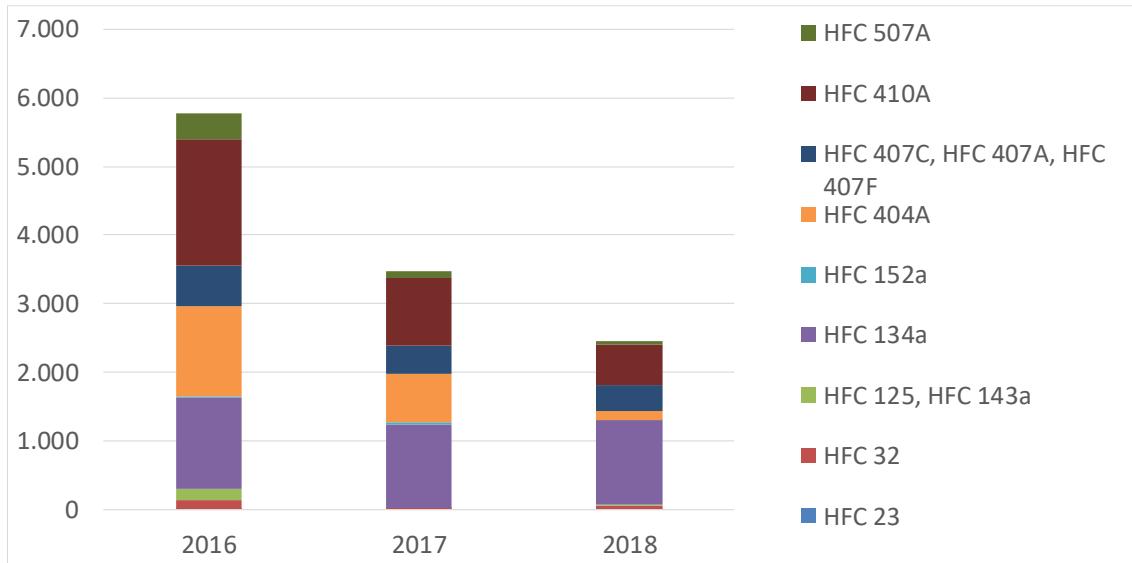
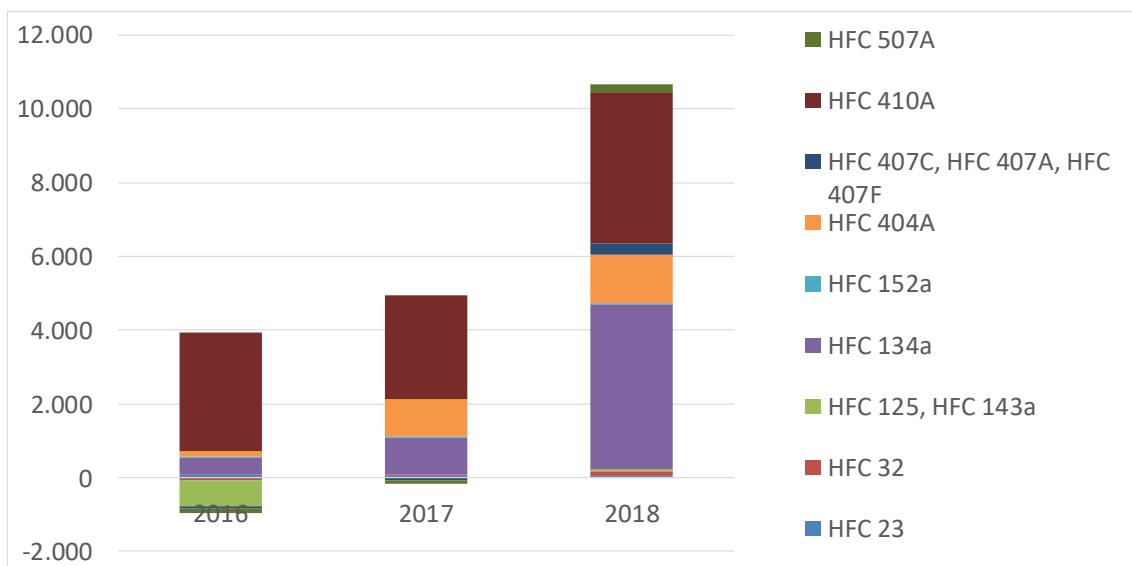


Figure 5: Export of HFCs (t)

In terms of CO₂-equivalents, the rise in net import is practically the same (a factor of 3,6) from 2016 to 2018)⁴.

Figure 6: Net import of HFCs (kt CO₂-eq)

This increase is surprising, given the strong quota reduction at EU level in the framework of Art. 15 of EU Regulation 517/2014.

⁴ A GWP value of 4000 has been assumed for 'HFC 125, HFC 143a' and 1900 for 'HFC 407C, HFC 407A, HFC 407F'.

The evolution for Belgium differs significantly from the one observed for the EU, as can be seen on Figure 7 and Figure 8, for which there is a rise in 2017, but a strong decrease in 2018, more pronounced in terms of CO2-eq.

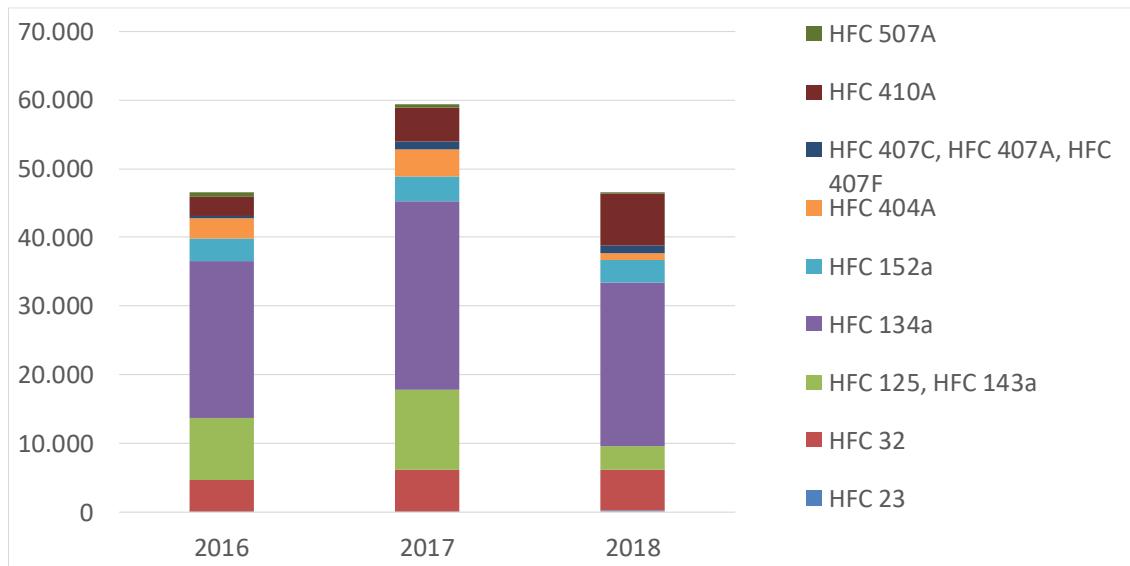


Figure 7: Net import of HFCs in EU (t)

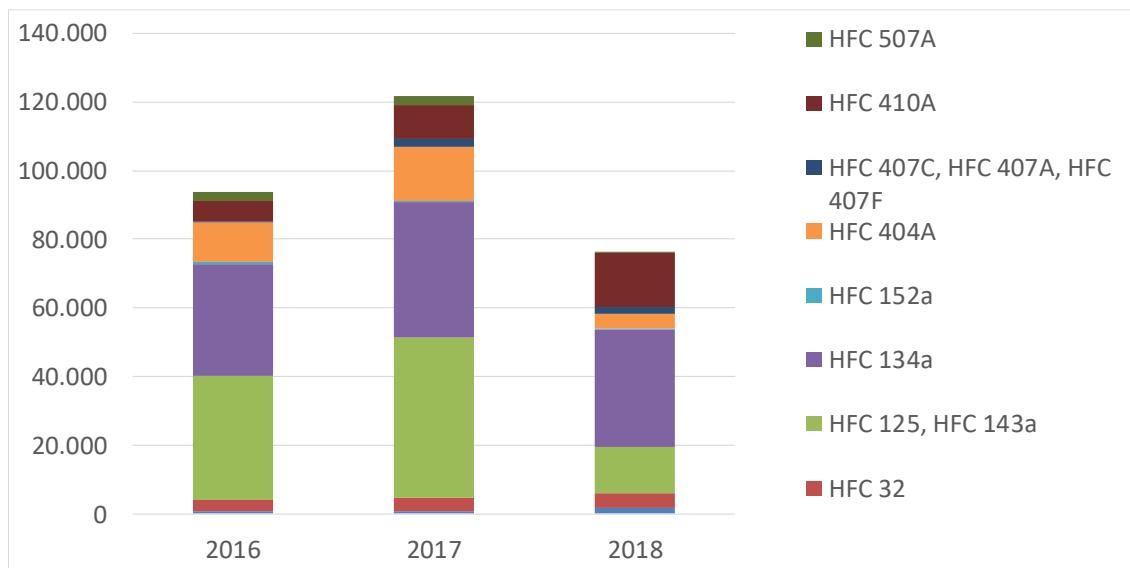


Figure 8: Net import of HFCs in EU (kt CO2-eq)

We don't have an explanation for this strong increase for Belgium. Stockpiling is probably playing a significant role. A better insight could be obtained by looking at data for individual companies, for example by identifying the sectors concerned, but such data are confidential, and we have no access to them. We suggest that an organisation having access to the relevant data be charged with addressing the matter.

5.2 Illegal trade

The entry into force of the HFC phasedown of EU regulation 517/2014 has given rise to illegal HFC import in Europe [6]. According to an analysis by the EU Commission [7], imports of HFCs declared at customs seem to be correctly reported under the FGR, and therefore most illegal trade appears to be in the form of an evasion of customs (cross-border smuggling). However, up to now it does not appear possible to quantify this customs evasion, even at EU level.

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 probably limited for the time being, we have decided to neglect it. In the meantime, action against illegal trade is being undertaken by the EU Commission, Member States and EFCTC [8], 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.

6 ANALYSIS BY SECTOR

The list of emission sources is given in Annex 2, together with their allocation to the source categories of the Common Reporting Format (CRF) of the UNFCCC.

6.1 Cooling applications

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

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

In accordance with the IPCC guidelines, the assembly emissions, the operation emissions 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 operation emissions 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.

An annual inquiry is made on the consumption of the major F-gas containing product manufacturers, among which the 4 car manufacturers.

6.1.1 Industrial and commercial refrigeration installations

Industrial and commercial 'installations' represent all on-site assembled systems for industrial & commercial refrigeration. They are the largest single source of F-gas emissions and are reported in the CRF format under '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 and stationary air conditioning devices is subtracted. Assumptions are made on the average loss rates. No distinction is made between industrial refrigeration and commercial refrigeration installations, as it is not possible to disaggregate the 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. 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 put on the market.

The disposal emissions are calculated, using equation 7.14, page 7.51 of the 2006 IPCC Guidelines [2], as the amount initially charged into new systems times the percentage residual charge, times one minus the recovery efficiency at disposal.

**EQUATION 7.14
EMISSIONS AT SYSTEM END-OF-LIFE**

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

where:

- $E_{end-of-life, t}$ = amount of HFC emitted at system 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, percent
- $\eta_{rec, d}$ = recovery efficiency at disposal, which is the ratio of recovered HFC referred to the HFC contained in the system, percent

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%. 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 of disposal loss factor for individual years (e.g. larger than 100%).

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”. However, this quantity remains quite uncertain, depends on the refrigerant and varies with time. The 25% recovery factor may be considered as a conservative value, tending to overestimate the emissions rather than underestimate them. In 2018 no increase has been observed in the amounts of recovered refrigerant, nor in the average recovery rate (the average recovery rate of HFCs – estimated as described – over the period 1998-2018 is 25%).

6.1.1.1 Survey on the supply of refrigerants

As for the previous updates of the emission inventory, a survey of the supply of refrigerants was carried out among the 7 supplier companies. All the companies have responded. The results up

to 2018 are shown in Table 5, and in graphical form on Figure 9 and Figure 10. The composition of the refrigerants is given in Annex 5.

Table 5: Total supply of fluorinated refrigerants in Belgium (+)

(tonnes)	2003	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018
HCFC	712,1	545,3	113,5	94,3	61,4	40,0	20,0	0,0	0,0	0,0	0,0
R22	655,2	506,6	113,5	94,3	61,4	40,0	20,0	0,0	0,0	0,0	0,0
R123 (*)	0,0	0,0	0,0	0,0	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	0,0	0,0	0,0	0,0
R409A	56,9	38,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
HCFC-HFC	32,6	23,5	0,0	0,8	0,2	0,1	0,0	0,0	0,0	0,0	0,0
R401A	7,3	3,6	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
R402A	2,4	2,0	0,0	0,6	0,0	0,0	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	0,0	0,0	0,0	0,0
R408A	21,6	16,1	0,0	0,2	0,2	0,1	0,0	0,0	0,0	0,0	0,0
HFC	709,7	831,4	1.090,3	1.110,7	1.047,7	1.031,4	1.103,0	1.042,3	996,4	907,3	582,7
R23 (*)	4,2	4,1	0,6	0,4	3,0	4,6	0,7	2,5	1,5	2,1	0,7
R32	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,5	6,3	14,6
R134a	296,6	335,3	413,2	448,3	438,1	399,3	467,2	413,4	430,5	389,7	265,5
R404A	261,0	308,5	322,2	332,4	290,9	300,0	281,1	240,0	216,9	197,5	62,8
R407A	0,0	0,0	0,0	0,0	0,0	1,0	2,9	0,8	1,8	1,1	0,5
R407C	79,0	80,2	96,9	83,7	70,7	75,3	76,1	79,6	69,1	67,6	47,8
R407F	0,0	0,0	0,0	0,0	0,0	9,1	28,8	40,1	38,4	27,4	15,3
R410A	9,2	22,1	88,2	87,1	96,7	88,3	85,4	126,4	121,2	125,7	139,6
R417A	0,0	3,9	11,1	6,4	3,3	13,4	7,8	5,9	3,4	3,5	1,6
R422A	0,0	0,0	0,0	5,1	4,5	3,1	0,6	3,1	1,7	0,8	0,4
R422D	0,0	0,0	16,8	25,7	18,8	18,7	27,9	28,2	23,7	14,2	6,1
R427A	0,0	0,0	7,5	6,1	6,1	6,7	6,9	7,1	4,0	4,3	3,4
R434A	0,0	0,0	0,0	0,0	0,0	0,0	3,0	4,0	0,0	1,3	1,8
R437A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5	0,1	0,1
R438A									0,3	0,4	0,4
R507A	59,7	77,2	133,7	115,4	115,7	112,1	114,7	91,2	81,0	65,1	22,4
HFC-PFC	12,3	6,4	0,9	0,4	0,3	0,3	6,1	0,0	0,1	0,0	0,2
R413A	12,3	6,4	0,9	0,4	0,3	0,3	6,1	0,0	0,1	0,0	0,2
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	16,0	44,4	103,0	179,1						
R448A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,0	6,0	24,7	42,1
R449A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	13,0	37,6	70,9	110,2
R450A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,5	2,1
R452A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,9	6,1	22,0
R454A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1
R454C	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1
R455A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
R513A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,8	2,6
HFO	0,0	0,0	0,0	0,0	0,0	2,0	2,2	2,4	8,4	5,5	9,8
R1234yf	0,0	0,0	0,0	0,0	0,0	2,0	2,2	2,4	6,9	4,5	8,9
R1234ze	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,5	1,1	0,9
Total géné	1.466,7	1.406,5	1.204,8	1.206,1	1.109,6	1.073,8	1.131,3	1.060,8	1.049,2	1.015,8	771,9

Excluding supply to original equipment manufacturers (OEM)

(*) Up to 2013 not necessarily complete

The latest survey shows a strong decline in the overall supply in 2018 (-24% compared with 2017), which is not surprising, given the strong quota reduction at EU level in the framework of Art. 15 of EU Regulation 517/2014, already mentioned about the external trade in section 5.

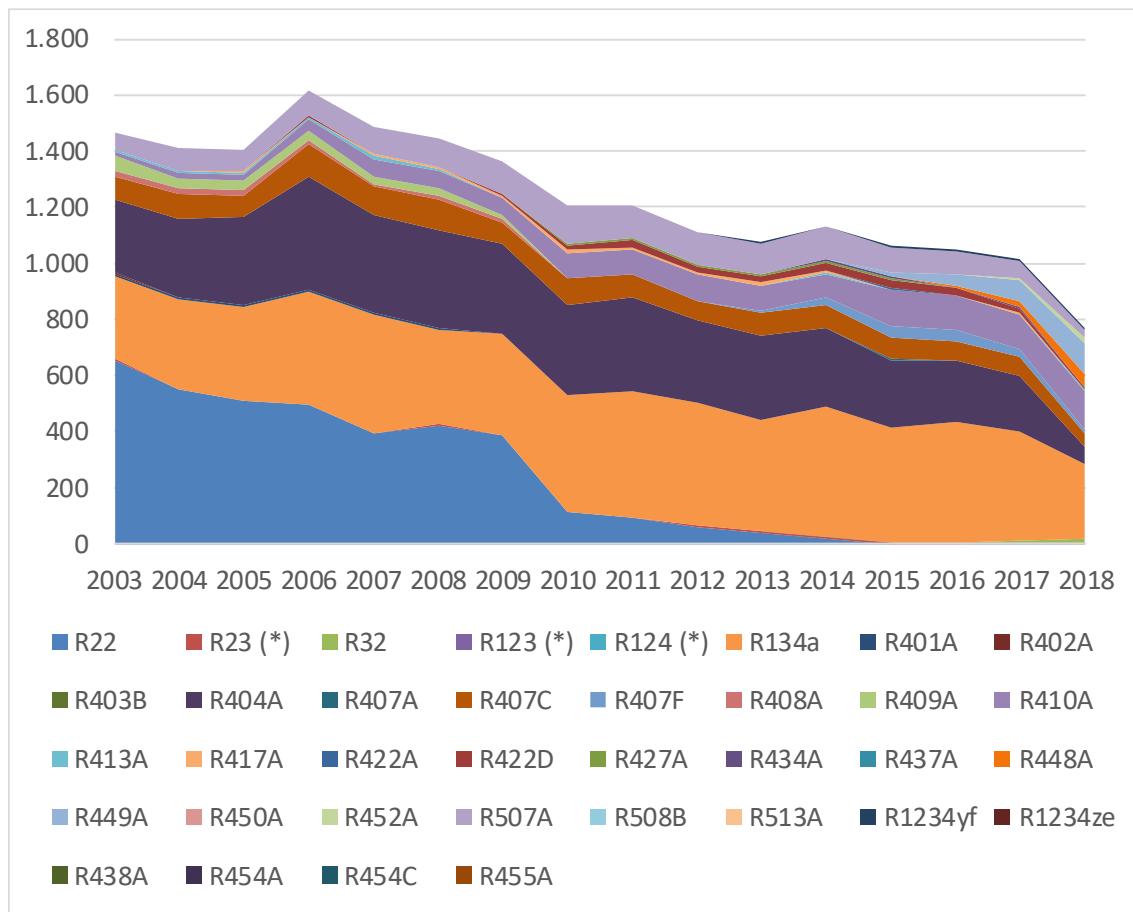


Figure 9: Supply of refrigerants in Belgium (tonnes)

The evolution by individual refrigerant is displayed on Figure 9 and Figure 10. One can notice the strong erosion of R404A and R134a, partly compensated by the penetration of R449A, a substitute for R404A.

Noticeable is that the supply of R410A, which is mainly used for stationary air conditioning, is still growing in 2018.

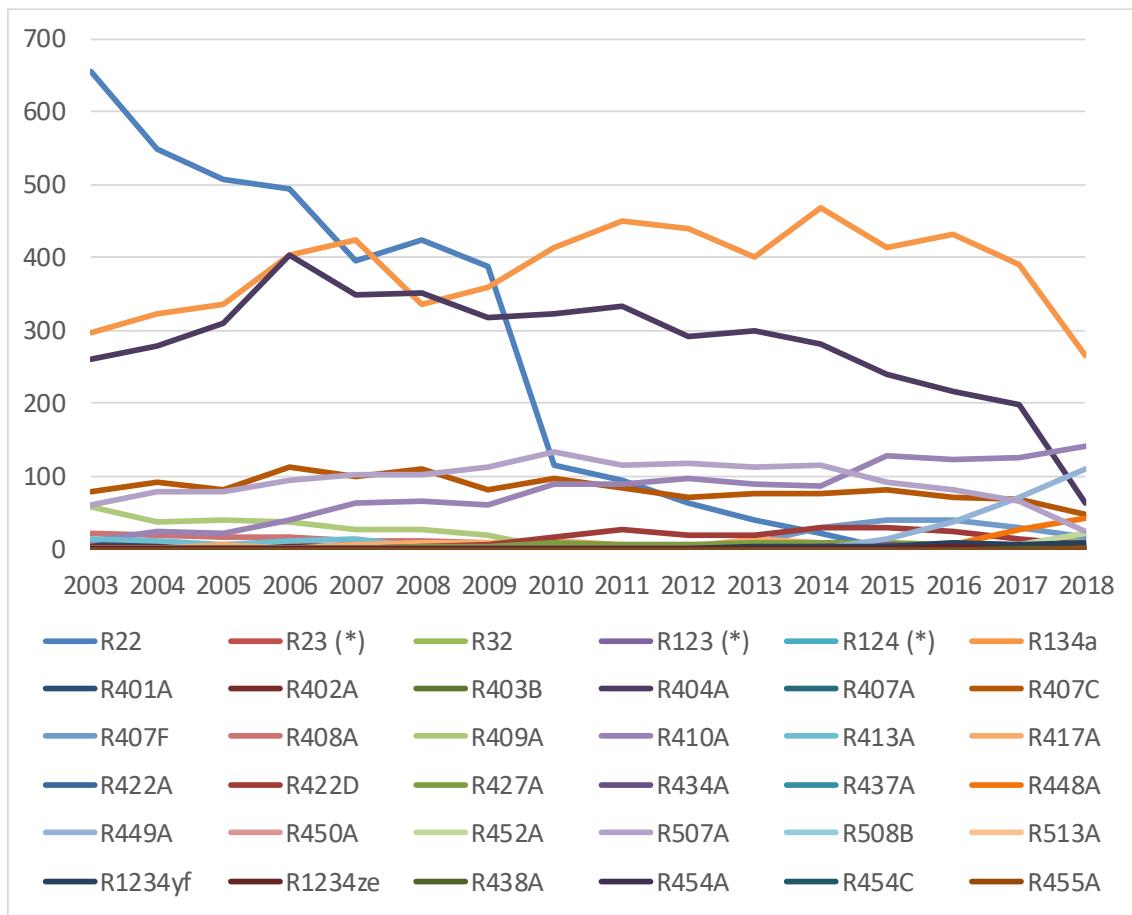


Figure 10: Supply of refrigerants in Belgium, by refrigerant (tonnes)

6.1.1.2 Annual leakage rate

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

For up to 2004, we had assumed a constant bank⁵ 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 2016⁶ (see Table 6 and Figure 11). Leakages still occur at a significant fraction of the investigated plants (in 2016, 43% of the inspected plants still had

⁵ 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.

⁶ 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 [47].

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 6: Results of inspection campaigns on refrigeration plants in Flanders

Year	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	59%

Source: "Milieuhandhavingsrapport Afdeling Milieu-Inspectie" for the years 2004-2016

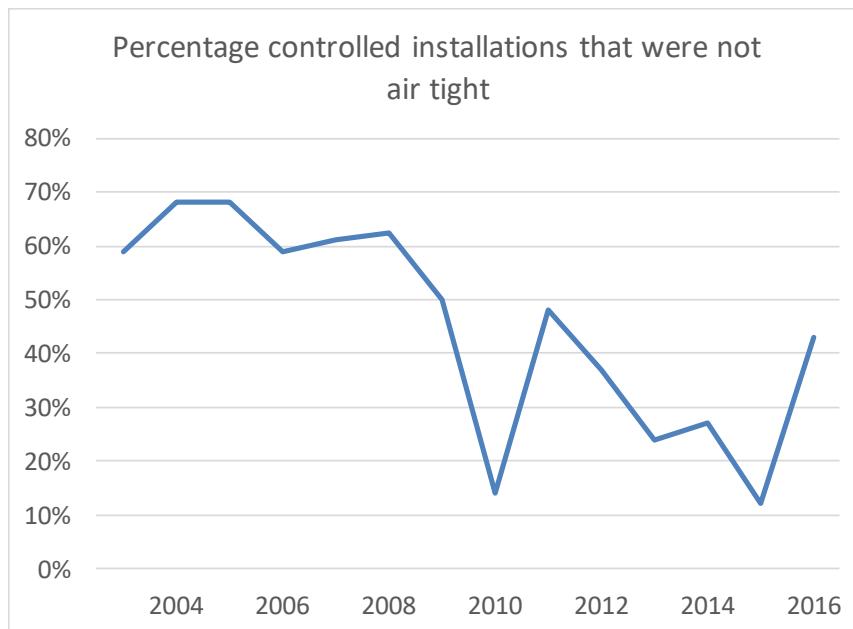


Figure 11: Percentage controlled installations that were not airtight in Flanders

Table 7: Leakage by refrigerant on refrigeration plants in Flanders in 2016

Refrigerant	Number of inspected installations	Leaking installations (%)	No. of leaking installations
R22	8	88	7
R507+R507A	27	48	13
R404A	24	62	15
R134a	38	55	21
R407+R407C	42	10	4
Total	139	43	60

Source: Milieuhandhavingssrapport 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 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 kept 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 type of decline afterwards. This leads us to a leakage rate of 8,1% in 2018.

For industrial and commercial refrigeration, this translates to a constant level of 22% until 1996, decreasing exponentially for HFCs to reach 10,5% in 2018.

In the framework of consultations that we held with service companies, operators, refrigerant suppliers and experts in the field of refrigeration or air-conditioning, this topic was addressed. Opinions are 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 moment. In the future, it is possible that better data will become available as a result of EU Regulation 517/2014⁷ and its enforcement by regional governments.

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 2018, to take into account the penetration or increased penetration of NH₃ systems and the penetration of CO₂ 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 (on which the latest report is [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 refrigerants are not used in new installations anymore in 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 the 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 retrofitting existing installations has been improved, 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). As a result, the disposal of the refrigerants replaced takes place earlier, and disposal emissions of R404A and R507A are higher during the years 2016-2018. This implies that future disposal emissions of these refrigerants will be lower. Given the mass balance approach, this modelling change does not affect the ‘amount in systems at time of disposal’ cumulated over time.

6.1.1.3 Disposal emissions

The recovery efficiency of disposal for these installations is assumed to be 25% at the end of life and 50% in the case of retrofitting (a higher value, as in case of retrofitting an installer is generally involved, who is more likely to recover the refrigerant that is to be replaced). 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 annual “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) and thus remains very uncertain.

⁷ Art. 6(1) of EU Regulation 517/2014 states that operators of equipment that contains fluorinated greenhouse gases in quantities of 5 tonnes of CO₂ equivalent or more and not contained in foams shall maintain records on the quantity and type of fluorinated greenhouse gases installed, any quantities added and the quantity recovered during servicing, maintenance and final disposal.

If the annual data of recovered fluorinated gases were used, the calculation would sometimes lead to unrealistic values of disposal loss factor for individual years (e.g. larger than 100%). However, 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”. On average, the disposal recovery factor is about 29%, which corresponds with the results of the surveys. The assumptions on the recovery efficiency thus do not appear unrealistic. They should be considered as underestimates (conservative values), however, as in the surveys parts of the amounts recovered are not disaggregated by individual substance and were not considered.

6.1.1.4 Results

Figure 12 shows the total emissions by refrigerant, in terms of CO₂ equivalents.

Dominant are R22 in the first place, progressively replaced by R404A, R507A and R134a.

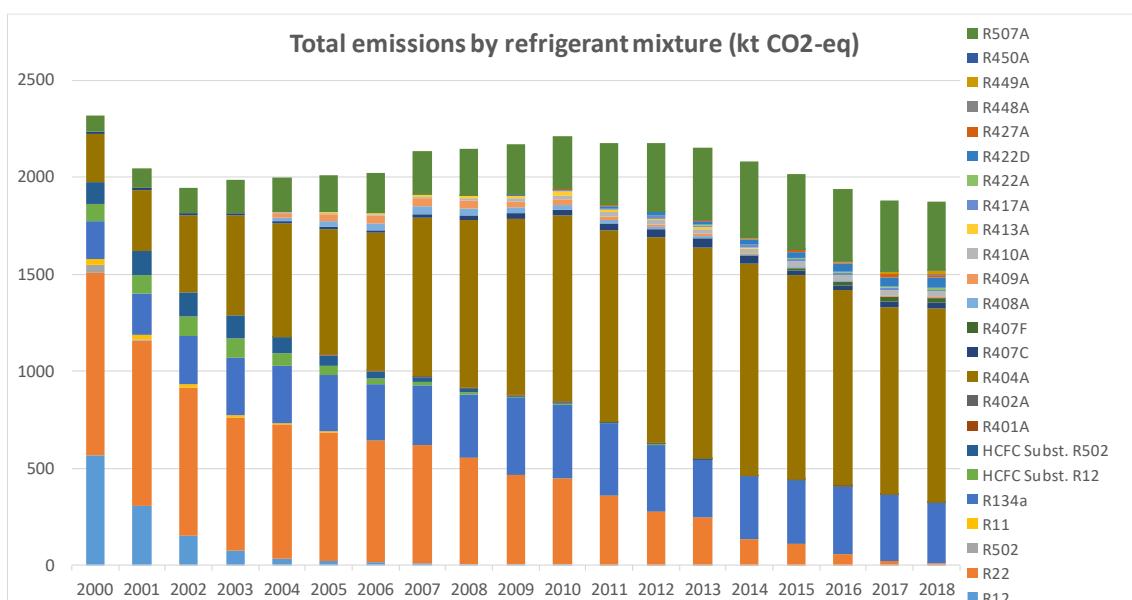


Figure 12: Emissions from industrial and commercial refrigeration by refrigerant (kt CO₂-eq)

The emissions of Kyoto-gases, expressed in CO₂-eq (shown by substance on Figure 13 and by type on Figure 14), 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.

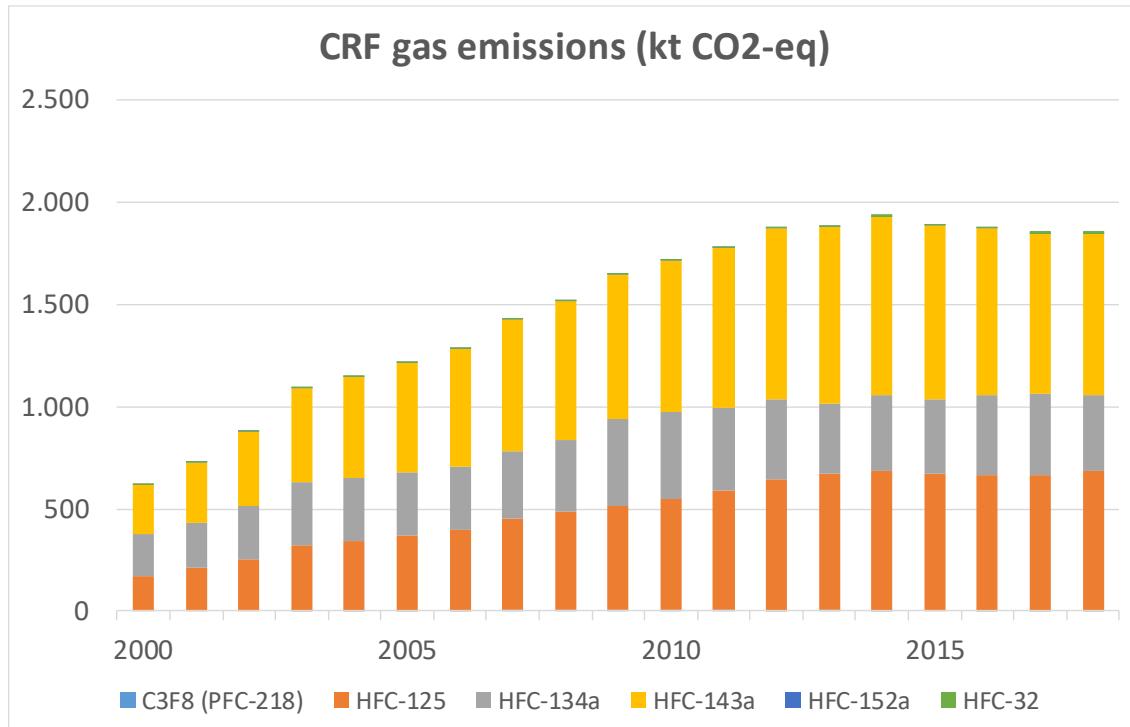


Figure 13: CRF-gas emissions from industrial and commercial refrigeration installations by substance (kt CO2-eq)

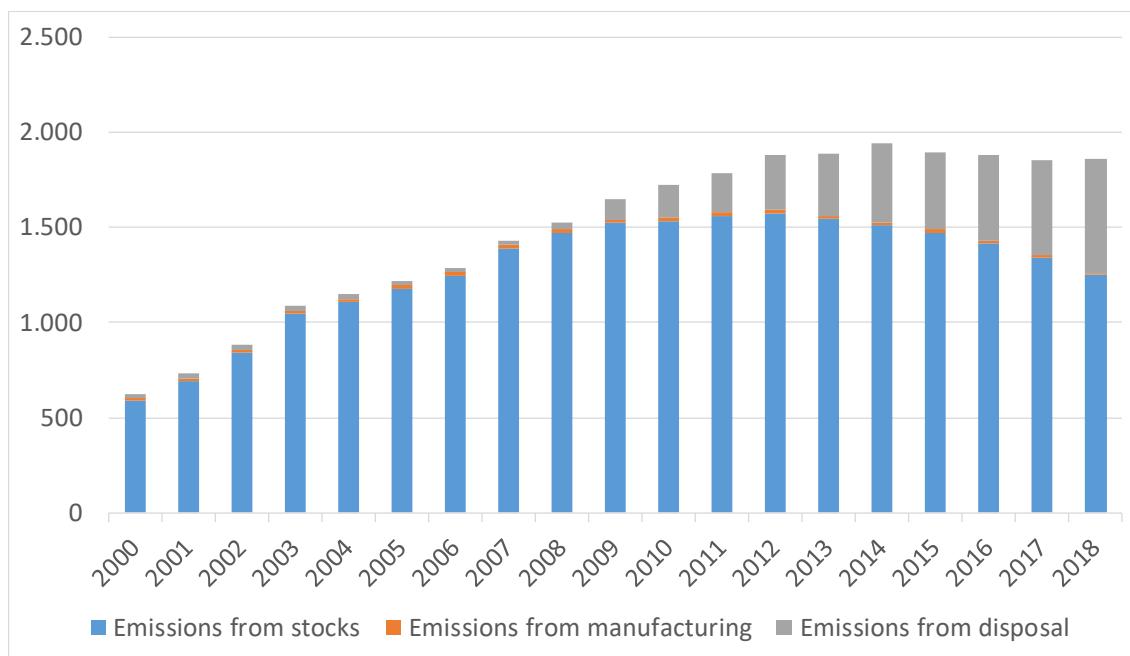


Figure 14: CRF-gas emissions of Kyoto-gases from industrial and commercial refrigeration installations, by type (kt CO2-eq)

6.1.2 Hermetically sealed refrigerators

For the calculation a difference is made between domestic and commercial refrigerators. Domestic refrigerators are divided into three categories: independent refrigerators, independent freezers and refrigerator/freezers. Commercial refrigerators include 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 pre-filled with refrigerants. Because no statistics are available differentiating between hermetically sealed commercial refrigeration types, no distinction is made.

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 in 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 survey⁸, 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 - 2015 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.

The number of new hermetically sealed commercial refrigerators is calculated based on the number of supermarkets and smaller shops in Belgium from 1995 to 2018. Statistics were used from [10] and published statistics from STATBEL. Equipment in smaller shops, e.g. food retail, restaurants, hotels, etc., not included in the 2017 inventory, were now included. Assumptions on the use (kg) of refrigerants in hermetically sealed refrigeration per shop (depending on its size) were taken from literature. Overall, the load per equipment is assumed to be 500 g on average. The most frequently used refrigerants are R134a and R404A. The shares of each have changed over the years, with increasing use of non-HFC refrigerants and decreasing shares of R404A because of its high GWP. The time series was reconstructed based on available literature and inventories from France and the UK.

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). For commercial refrigerators the emission factor is also 1%.

⁸ 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.

EQUATION 7.13
SOURCES OF EMISSIONS DURING EQUIPMENT LIFETIME

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

Where:

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

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

x = annual emission rate (i.e., emission factor) of HFC of each sub-application bank during operation, accounting for average annual leakage and average annual emissions 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 is end of life in 2018 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.

Commercial refrigeration has an average lifetime of 10 years. With respect to disposal, commercial refrigerators are in some cases also collected via the Recupel system but not for all. To calculate the disposal emissions, the same assumptions were used as for domestic appliances. The study [11] 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 installations that are disposed correctly and those that are disposed incorrectly with high emissions as a result.

Emissions from disposal (see IPCC methodology below) are assumed to occur at two different stages of the process:

- i. on site, during collection, storage and transport from the collector to the dismantling plant and when disposed incorrectly; and
- ii. at the dismantling plant.

The emission factor for the first type of emissions is assumed to be 30% and occurs at the region where refrigerators and freezers originate from. Recent information from Recupel showed that around 30% of domestic refrigerators are not dismantled correctly. This is an adjustment compared to previous inventory, where it was assumed to be 20%.

EQUATION 7.14
EMISSIONS AT SYSTEM END-OF-LIFE

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

Where:

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

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

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

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

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 that, 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 2018, which is a conservative estimate.

Table 8: Assumptions for household refrigerators and comparison with IPCC 2006 guidelines

	HFC-134a	HFC-245fa	IPCC 2006
Charge (kg)	0.1	0.325	0.05 < M < 0.5
Lifetime (y)	15	15	12 < d < 20
Manufacturing EF (%)	NA	NA	0.2% < EF < 1%
Fugitive EF (%)	1% ¹	0,25%	0,1% < EF < 0,5%
Recovery efficiency (%)	72% ²	90%	0% < RE < 70%

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).

Table 9: Comparison of assumptions for domestic refrigerators between selected countries (in 2017)

Assumption	BELGIUM	GERMANY	UK
Disposal EF (%)	36%	27%	28%
Fugitive EF (%)	1%	0,30%	0,30%
Manufacturing EF (%)	NO	NO	0,60%
Lifetime (y)	15	15	15
Charge (g)	100	NR	100
Share R134a new (%)	0%	0%	0%

Table 10: Comparison of assumptions for commercial hermetically sealed refrigerators between selected countries (in 2017)

Assumption	BELGIUM	GERMANY	UK
Disposal EF (%)	36%	34-54%	28%

Fugitive EF (%)	1%	1% - 1,4%	1,2%
Manufacturing EF (%)	NO	NA	1%
Lifetime (y)	10	10	10
Charge (g)	500	NA	500
Share R404A new (%)	7%	NA	NA
Share R134a new (%)	36%	NA	NA

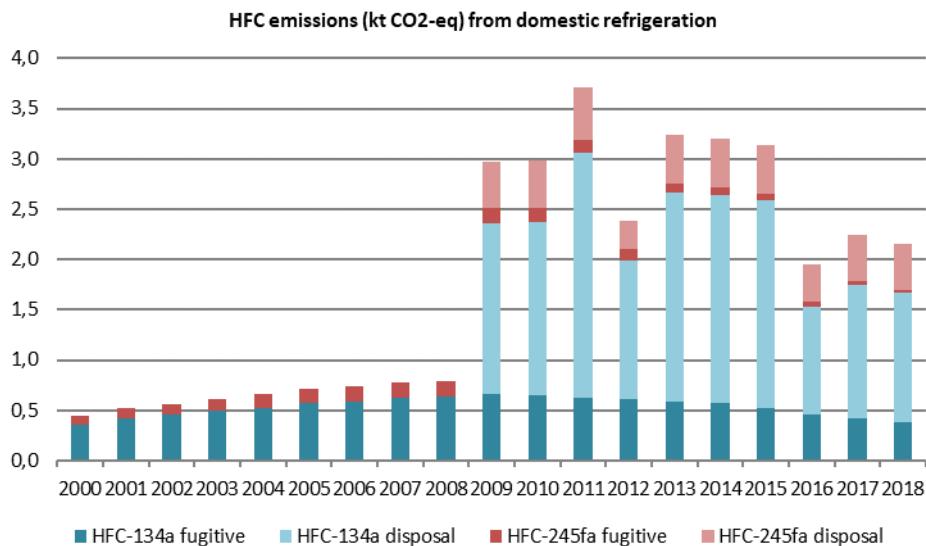


Figure 15: Emissions from hermetically-sealed domestic refrigeration (in kt CO2-eq)

6.1.3 Stationary air conditioning

This source category comprises chillers, 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 2018.

Room air conditioners and heat pumps have been accounted for in the inventory since 2007. Data on the sales of room air conditioners and heat pumps were requested from UBF-ACA (Air Conditioning Association). UBF-ACA is the most representative organisation of market players in this sector. Sales data are available for 2005-2018. For 2012-2018 UBF-ACA provided statistics, but the format was different than in previous years. We therefore have only taken the total quantity of equipment placed on the market and split this among the different categories (e.g. mobile, split, multi-split) based on the division in 2011.

The sales of movable air conditioners in the inventory was lower than recently received statistics from other studies. The assumption was adjusted for the period in 2017.

Chillers used to be considered under ‘Industrial and commercial installations’, however the recent study for Flanders on disposal emissions [11] showed that most chillers are pre-filled. We therefore included them now in this category. Sales statistics were available for the period 2005-

2011 from UBF-ACA. For the period 2012-2018, the number of chillers placed on market was estimated based on the total sales of air conditioning and heat pumps. This corresponds well with estimates made for Belgium by BSRIA [12]. 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 [12], made an assumption 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 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 masks 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 [13] were used to estimate the quantity of refrigerants per unit.

The disposal emissions are assumed to be 70%, based on [14].

Table 11: Assumptions for room air conditioners and heat pumps and comparison with the IPCC 2006 Guidelines

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

¹ Residential and commercial, including heat pumps.

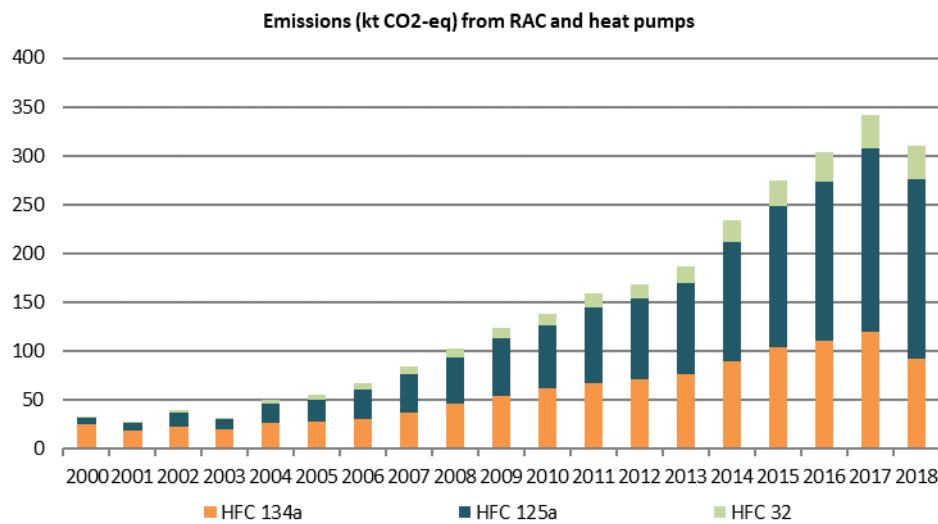


Figure 16: CRF emissions from chillers, room air conditioning and heat pumps (in kt CO2-eq)

Table 12: Comparison of assumptions for chillers, room air conditioning and heat pumps between selected countries (in 2017)

Assumption	BELGIUM	GERMANY	UK
Manufacturing EF (%)	0,07%	0,5 - 10%	0,5 - 1%
Charge (kg)	0,5 - 6,2 kg	NR	1,8 - 15 kg
Charge chillers (kg)	100 kg	10 – 630 kg	180 kg
Lifetime (y)	15	10 - 15	13 - 18
Lifetime chillers (y)	15	15 - 25	18
Fugitive EF – movable (%)	2,5%	2,5 – 3,4%	5 - 6%
Fugitive EF – split (%)	4%	5 – 7%	5 - 6%
Fugitive EF – multi-split (%)	5%	5 – 8%	5 - 6%
Fugitive EF – chillers (%)	3,8%	3 - 6%	3,7%
Disposal EF (%)	70%	18 - 76%	18 - 25%
Disposal EF chillers (%)	70%	22 - 34%	7%

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.

6.1.4 Air conditioning in private cars

A questionnaire has been sent to all car manufacturers in Belgium asking for their consumption of HFC-134a and HFO-1234yf in 2018 and their emissions.

Data on the total number of cars produced in Belgium over the past year were obtained from FEBIAC [15] and the number of new cars registered in Belgium from the national statistics office [16].

To calculate the emissions from car air conditioning systems, the share of new cars equipped with air conditioning systems must be known. For 2018 the share is estimated to be 96%. This is assumed to be the maximum saturation level, based on Schwartz [17]. We have assumed that in Belgium this value was reached in 2010. In Belgium, no systematic registration of new cars 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 lifted⁹. 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 with approximately 1% of the total car fleet or 6,2% of cars sold [18]. In Belgium, we assume that 1,4% of cars sold in 2013 contain HFO-1234yf¹⁰, 6% in 2014, 24% in 2015, 82% in 2016 and 100% in 2017 taking into account a gradual increase in number of cars.

⁹ 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

¹⁰ 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.

It is assumed that CO₂ 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 CO₂-eq.

An important assumption is the amount of HFC-134a 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).

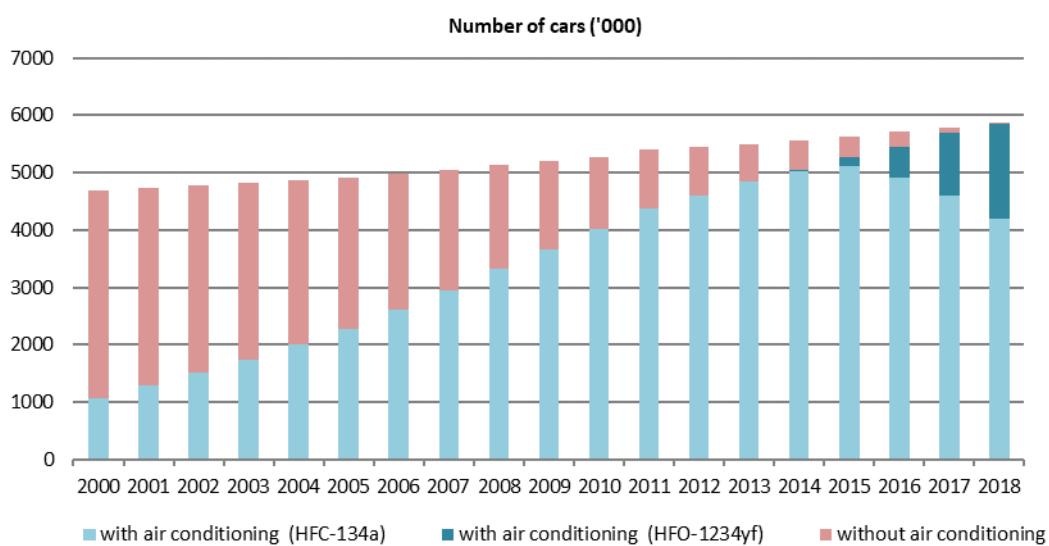


Figure 17. Stock of cars in Belgium with and without air conditioning

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 in Belgium. 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 [19]. There are two possible explanations: either the model overestimates or the statistics of Febelauto are not complete.

If the model overestimated the number of cars that are removed from the park, we would expect the total number of cars based on the model to be much smaller than the total registered cars statistics, published by the national statistics office. This is not the case (a comparison revealed that the difference between the two is 6,5% in 2018).

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. 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).

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 2017, this is 68%. Previously, the percentage was 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 could be relatively older and/or equipped less with air conditioning than average (Febelauto, 2016; pers. comm. 2016).

The fugitive emission factor for cars 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, assuming only one refilling over the lifetime of the car and with smaller emissions (2%).

Table 13: Assumptions for mobile air conditioners and comparison with IPCC 2006 guidelines

Assumptions	Car	Bus	Truck	Train	IPCC (2006)
Charge (kg)	0.5	11	0.9 – 11	40	0.5 < M < 1.5
Lifetime (y)	11	17	12	12 – 28 ⁴	9 < d < 16
Manufacturing EF (%)	Variable ¹	1%	1%		0,2% < EF < 0,5%
Fugitive EF (%)	8,8% ²	15%	8 – 11% ³	6,2%	10% < EF < 20%
Recovery efficiency (%)	9% ⁵	70%	70%	NA	0% < RE < 50%

¹ based on information from car manufacturers, big difference between theoretical and measured emission factors.

² Schwartz, 2005

³ Schwartz, 2007

⁴ and 213 kg for High Speed Train

⁵ excluding export.

Table 14: Comparison of assumptions for car air conditioning between selected countries (in 2017).

Assumptions	BELGIUM	GERMANY	UK*
Manufacturing EF (%)	2,5%	3 g/system	0,50%
Share HFO-1234yf (%)	100%	NA	NR
Charge (g)	500	NR	700
Lifetime (y)	11	15	15
Fugitive EF (%)	8,8%	10%	8%
Disposal EF (%)	91%	54 - 62%	25%

* Passenger cars and light-duty commercial vehicles.

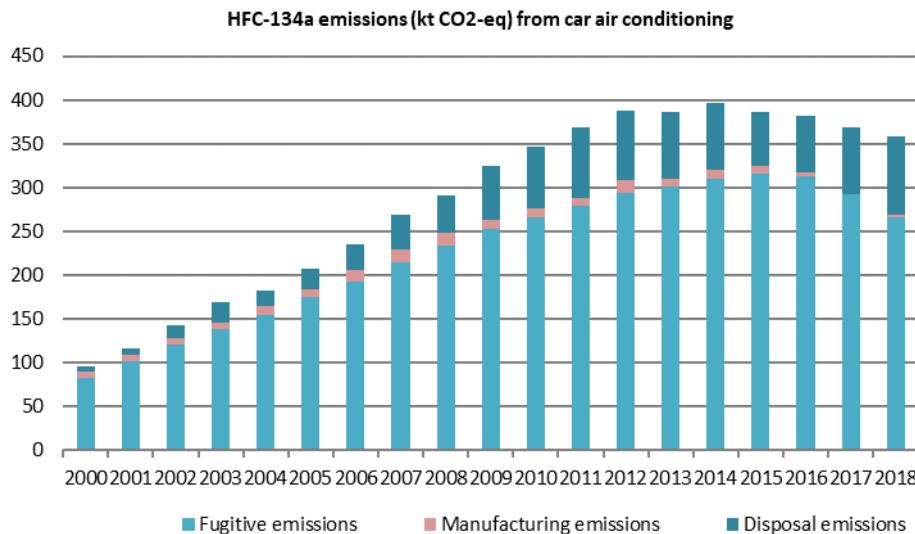


Figure 18: Emissions from car air conditioning (in kt CO₂-eq)

6.1.5 Air conditioning in 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 R-407C (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 [16] and divided among buses and coaches. This assumption was adjusted based on new information on the share of public buses, private buses and private coaches.

The data is split between buses (public and private) 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 60% of buses are equipped with air conditioning. The percentage buses with air conditioning was recalculated based on information on the number of buses of De Lijn, TEC and MIVB. We assume a percentage of 60%, also used previously. From 2018 onwards all new public buses are assumed to be air conditioned. For private buses, the share of buses equipped with air conditioning is lower and only 15%.

We use a model approach to estimate the number of buses and coaches in the entire fleet with air conditioning. In 2018, 50% of buses and coaches had air conditioning. The total fleet of buses and coaches for 2018 was obtained from the national statistics office. Fugitive 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, where recharging only takes place once.

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 by Germany.

Table 15: Comparison of assumptions for bus air conditioning between selected countries (in 2017).

Assumptions	BELGIUM	GERMANY	UK*
Manufacturing EF (%)	2,40%	50 g/system	0,50%
Charge (kg)	11 kg	NR	4 kg
Share R134a (%)	78%	NR	NR
Lifetime (y)	17	15	10
Fugitive EF (%)	15%	15%	9%
Disposal EF (%)	30%	62%	18%

NR = Not reported in NIR

* other mobile air-conditioning, meaning trucks, buses, trailers and railcars.

6.1.6 Air conditioning in trucks

Information on refrigerant use and emissions of manufacturing was obtained from the only Belgian manufacturer. There is a significant 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 (14% in 2018). For the inventory, we used an emission factor of 1%.

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]). Road tractors were included to the high weight category. For each weight category, different assumptions are taken with respect to percentages of new vehicles equipped with air conditioning. The assumption on the share of new vehicles with air conditioning was adjusted upward.

Table 16: Comparison of assumptions for truck air conditioning between selected countries (in 2016)

Assumptions	BELGIUM	GERMANY	UK*
Manufacturing EF (%)	1%	5 g/system	0,50%
Charge (kg)	0,85 - 1,08 kg	NR	4 kg
Share R134a (%)	88%	NR	NR
Lifetime (y)	12	15	10
Fugitive EF (%)	8 - 11%	15%	9%
Disposal EF (%)	30%	54 - 62%	18%

NR = Not reported in NIR

* other mobile air-conditioning, meaning trucks, buses, trailers and railcars.

Fugitive emission factors are taken from [20], 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), at this moment the number of vans equipped with HFO-1234yf is limited but it is assumed that their penetration follows that of passenger cars (100% HFO-1234yf in 2018).

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.

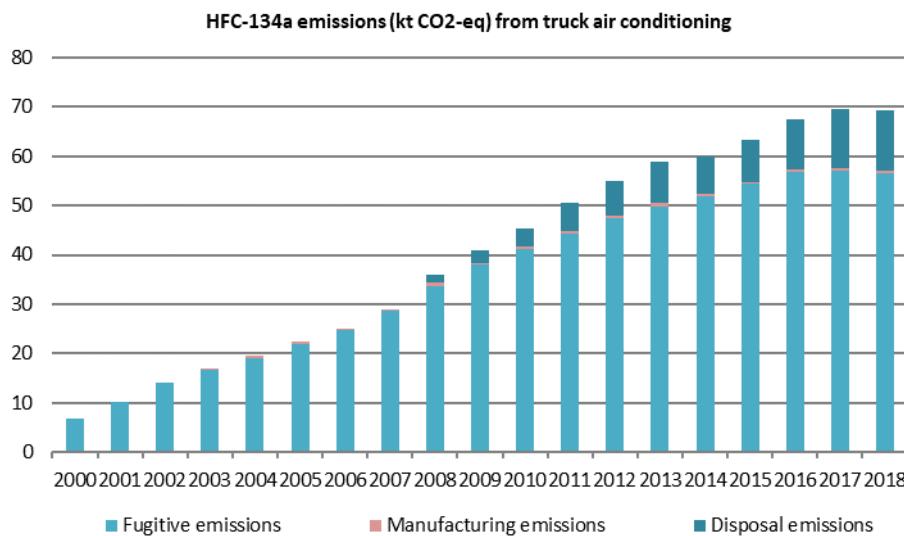


Figure 19: Emissions from truck air conditioning (in kt CO₂-eq)

6.1.7 Air conditioning in rail transport

There are relatively few trams and metros, so this source was excluded in this assessment. In contrast, an important part of the trains do have air conditioning. Information of the SNCB was requested on the number of trains with air conditioning in 2018, but not yet received. The vehicle fleet with air conditioning is slowly increasing.

The average quantity of HFC-134a per vehicle, by type, will be 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 fugitive emissions, an emission factor of 4,7% (HFC-134a) and 23% (HFC-407c) was used (data from the NMBS/SNCB on use of HFCs for refilling air conditioning systems).

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 2023.

Table 17: Comparison of assumptions for train air conditioning between selected countries (in 2017)

Assumptions	BELGIUM	GERMANY	UK
Manufacturing EF (%)		0,50%	NR
Charge	12 - 14,5 kg	NR	NR
Share R134a	91%	NR	NR
Share R407C	9%	NR	NR
Lifetime	40	25	NR
Fugitive EF (%)	5%-23%	6%	NR
Disposal EF (%)	15%	24%	NR

NR = not reported in NIR

6.1.8 Refrigerated transport

This section concerns refrigerated trucks and trailers¹¹. Data on the fleet and new registrations of refrigerated trucks and trailers for 2018 were obtained from the FPS Mobility for different weight categories. The stock is relatively stable.

Manufacturing emissions are set to zero. However, filling of empty systems does occur. Emissions are included in the annual fugitive emissions.

The data shows that in the period 2009-2013 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. From 2014 onwards, the statistics were considered reliable. In For 2018, registrations data were adjusted to account for missing information on whether or not a truck was refrigerated. The fleet 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 F-gases in each weight category is based on assumptions taken from [13] and personal communication. Based on this new information, assumptions have been adjusted for the smallest weight category (2-5 t): from 100% R134a (2 kg) to 50% R134 and 50% R404A (1,5 kg) starting from 2010 to 2016. From 2017 onwards, also a rapid replacement of R404A with R452a should be considered. It is assumed that share of R404A is reduced to 10% in 2018 for all types of applications.

Fugitive 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.

¹¹ As far as maritime transport is concerned, the emissions of refrigerated containers (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 (see section17). 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 18: Comparison of assumptions for refrigerated transport between selected countries (in 2017)

Assumptions	BELGIUM	GERMANY	UK
Manufacturing EF (%)	NO	5 g	0,20%
Lifetime (y)	12	10	7
Fugitive EF (%)	15%	15%-30%	9%
Disposal EF (%)	30%	34%	12%
Charge	1,5 kg - 9 kg	NR	3,3 kg
2-5t: Share R134a	50%	NR	NR
2-5 t: Share R404A	25%	NR	NR
2-5 t: Share R452A	25%	NR	NR
5-9t: Share R134a	50%	30%	NR
5-9t: Share R404A	25%	50%	NR
5-9t: Share R452A	25%	10%	NR
9-22t: Share R134a	10%	10%	NR
9-22t: Share R404A	40%	65%	NR
9-22t: Share R410A	10%	10%	NR
9-22t: Share R452A	40%	15%	NR
>22t: Share R134a	5%	5%	NR
>22t: Share R404A	43%	20%	NR
>22t: Share R410A	10%	10%	NR
>22t: Share R452	43%	65%	NR

NR = not reported in NIR

6.1.9 Organic Rankine Cycle (ORC)

There are no IPCC 2006 guidelines for calculating emissions from ORC. This category is not included in reporting by many Member States. Germany started reporting on HFC emissions specifically for ORC from 2014.

The ORC is used for generating electricity from heat sources with temperatures and pressures that are too low for steam-powered generation. ORC systems are used especially in geothermal power generation and in harnessing of waste heat from combined heat and power (CHP) stations and biogas plants.

In Germany, C5F12 was first used as a working medium – in an ORC pilot system – in 2003. HFC-134a was used for the first time in an ORC system in 2008. Beginning 2011, several systems were commissioned that operate with HFC-245fa and with "Solkatherm", which consists of HFC-365mfc (65 %) and a perfluorinated polyether with the trade name "Galde" (35 %).

The largest fill quantities are up to 75 t and are used in geothermal applications. Considerably smaller fill quantities (0,2 to 0,6 t) are used in systems that harness waste heat from biogas plants and in compact CHP generating systems. The German inventory uses emission factors of 2% (manufacturing) and 4% (fugitive). For small ORCs, this would mean an annual emission of 8 to 24 kg, which corresponds with 8 to 25 t CO₂-eq. if HFC-245fa is used (which is the most applied in Germany).

The market for ORC has been growing steadily since the year 2000 and has been implemented in Belgium. Statistics on the number of ORC installations is however not available to our knowledge. In Germany, total HFC emissions from ORC are estimated to be 9,7 t in 2016. According to <http://orc-world-map.org/> there are only 9 ORC installations in Belgium, compared to close to 200 in Germany.

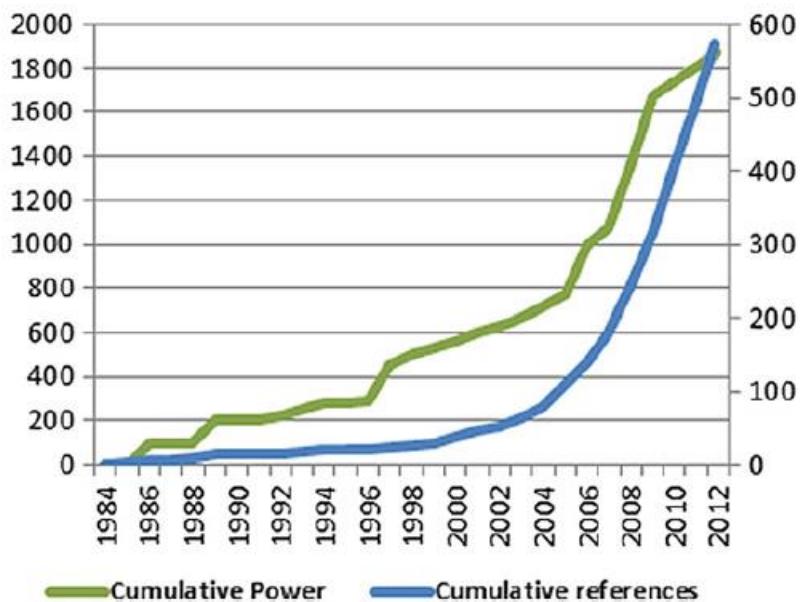


Figure 20. Market evolution (green, left) and share of each application in terms of number of units (blue, right) [21].

6.1.10 Tractors

Air conditioning in tractors or agricultural vehicles are not often included separately in inventories of other countries¹². Germany and Austria included information on emissions from agricultural vehicles in their NIR. Based on this information and data on registered tractors in Belgium an estimation was done of HFC emissions. The emission factors for fugitive and disposal emissions were estimated to be respectively 15% per year and 30%. The share of new tractors with air conditioning was assumed to be 95% in 2016 (but the share has increased from a marginal share in 1995 to this 95% in recent years).

The total emissions in 2018 reached a level of 12 kt CO2-eq., including fugitive and disposal emissions.

6.1.11 Reefers

To estimate emission from maritime reefers, Germany's approach has been to calculate global emissions and to allocate a share of these to Germany based on the German share of global trade.

¹² Not included separately for instance in France, the UK and Sweden.

Statistics on the number of reefers is not available. The Flemish harbour commission publishes data on the container traffic in number of TEU (Twenty Foot Equivalent Unit). Based on personal communication with the harbour authorities, an estimated 7% is assumed to be refrigerated. Reefers contain 4 (R404A) to 6 kg (R134a) each on average. While R134a was predominantly used in the past, there has been a shift to more R404A (approximately 50% each in recent years, see also the NIR of France).

The fugitive emission factor was estimated to be 5% per year in recent years [22], while historically the emission factor is estimated to be 15% (which is still used by France and Germany).

While information is available on the container traffic, there is no information on the time containers remain in Belgium. Reefers owned by Belgian companies can stay on shore for as long as several months, but emissions are estimated to be low.

Disposal emissions are not occurring often. Many reefers that are end-of-life in Belgium are either exported to outside the EU or used as temporary stationary refrigeration (e.g. for shops). It is not clear what happens with the refrigerant afterwards [11].

6.1.12 Heat pump dryers

Heat pump dryers have been on the EU market since 2004 and their penetration is increasing. In Switzerland, already 100% of the tumble dryers are heat pump dryers (data from the Swiss Association of the Domestic Electrical Appliances Industry cited in [23]). The share in the EU is lower though. In Germany, it was estimated to be 39% in 2012.

Dryers are equipped with either HFC-134a or R407C, with quantities ranging between 220 to 430 g [24]. The systems are hermetically sealed and for the German inventory in 2014 the fugitive emission factor is 0,3% but the Swiss inventory uses an annual fugitive emission factor of 2%. For our assessment, here we use the average emission factor of 0,3%.

Based on this information, we estimated the scale of emissions from heat pump dryers in Belgium. This was based on generalisations and assumptions that do not warrant inclusion of this emission source in the inventory. For instance, the share of heat pump dryers equipped with HFC-134a or R407C is not known, and we assumed this to be 50% for each gas. Also, 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 83% in 2017)¹³. Finally, it is assumed that 60% of households have a tumble drier, based on the household budget survey of 2010.

With these assumptions, emissions are estimated to be in the range of 1,4 kt CO₂-eq. in 2018. This is only a small quantity of total HFC emissions, but could increase in future as the stock of heat pump tumble driers increases over time. Currently, HFCs are predominantly used in tumble driers, but as the importance of this emission source increases or if HFC prices increase due to the F-gas regulation, HFCs could be replaced by low GWP alternatives in future [25].

¹³ Statistics for Belgium are not available, but this assumption is not unreasonable considering that between 57 and 62 % of all tumble drier models sold by 4 online retailers have heat pump technology.

6.2 Foams

6.2.1 Closed cell foams

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).

Figure 21 below recalls that HCFCs 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, but also for PU 2-component spray foam. Meanwhile, a growing quantity of HFOs is being used (40 t in 2018): 1234ze since 2013 and 1233zd and 1336mzz since 2018.

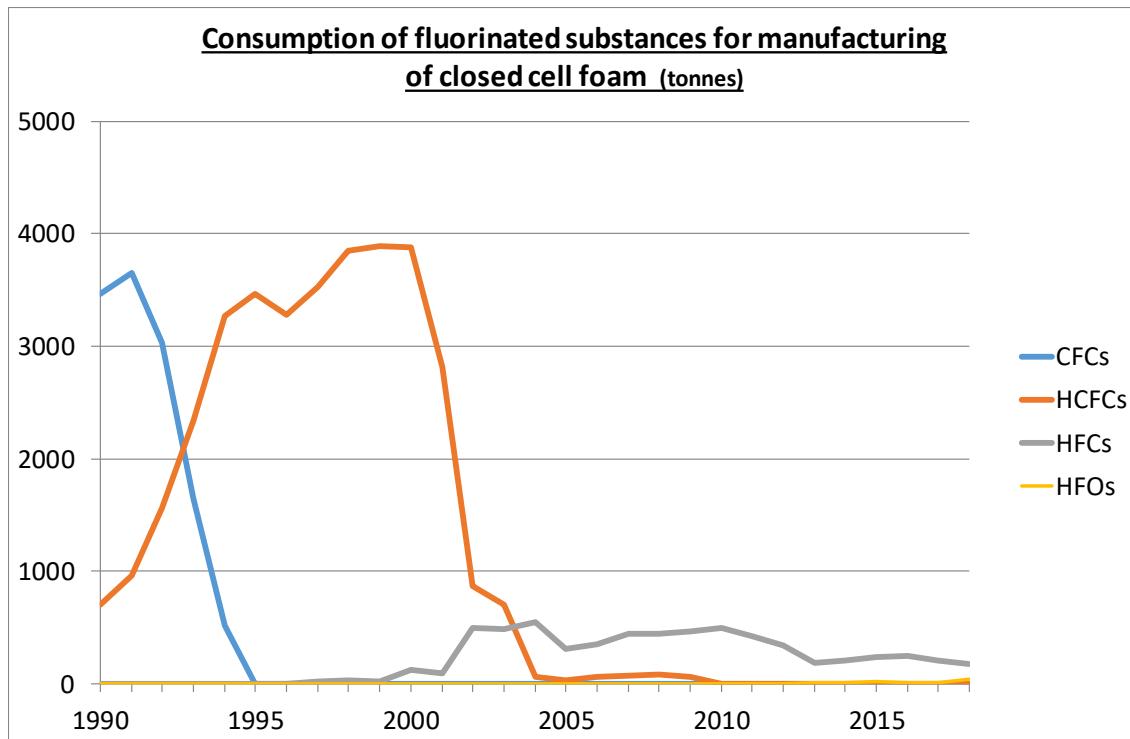


Figure 21: Consumption of F-gases for foam manufacturing (t)

The evolution of emissions in terms of CO₂ equivalent is shown on Figure 22, where one can notice the impact of the regular decline of existing stocks of CFCs and HCFCs, which are still dominant.

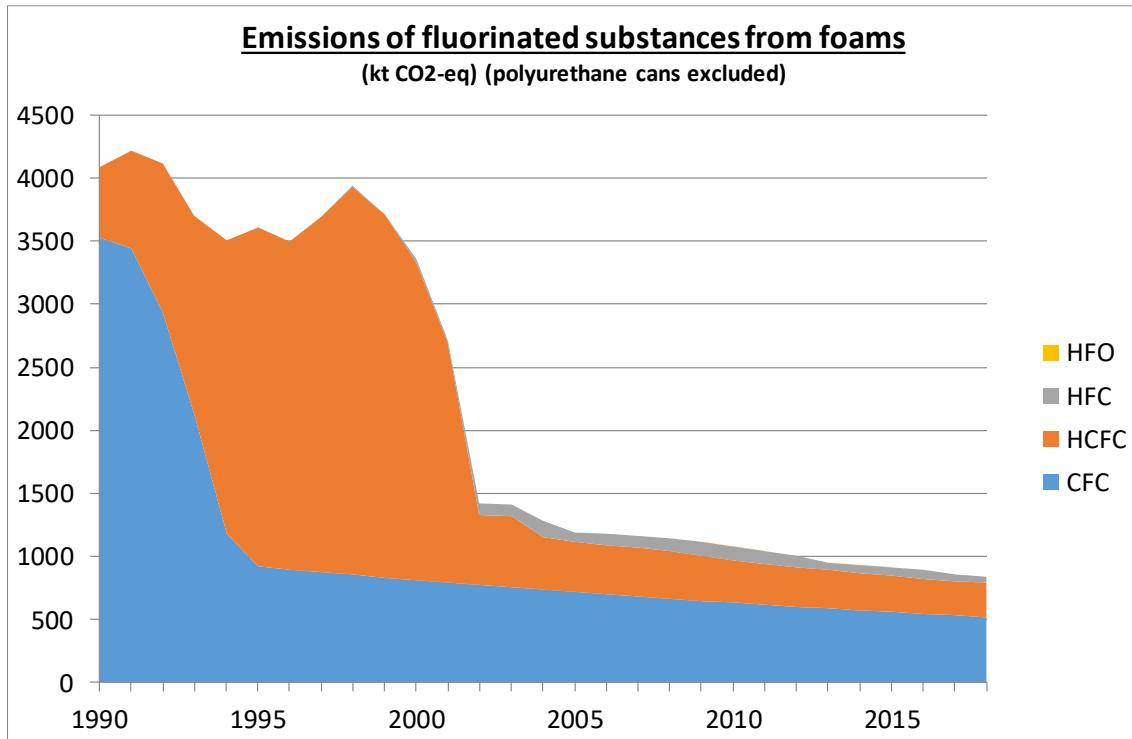


Figure 22: Emissions of F-gases from foams (kt CO₂-eq)

6.2.2 Polyurethane cans

There remains only one manufacturer of polyurethane cans (also called One-Component-Foam) in Belgium. Its consumption figures have been obtained directly from the company.

Since 4 July 2008, EU Regulation 842/2006, replaced by EU Regulation 517/2014, prohibits placing on the market in the EU ‘one component foams’ containing mixtures with a GWP of 150 or more, except when required to meet national safety standards. This allows to use 100% HFC-152a (with a GWP of 140) or up to 11,5% HFC-134a (with a GWP of 1300), if the remaining gas has a GWP of 0.

This explains why the HFC-134a consumption has decreased to close to zero and that of HFC-152a has substantially increased in 2008.

In the years 2000, to estimate the emissions from the use of PU cans has become more difficult, with the appearance of new products (high-yield foam, fire protection foam, winter foam, fountain foam, two component foam) besides the general purpose one component foam, and the fact that different manufacturers adopt different strategies regarding the use of HFCs. There are indeed no statistics on what is sold on the national market.

In Germany, statistics on the number of cans used and their average HFC content and composition have become available through the PU cans recycling systems that has been put in place. The German emission inventory has been revised based on these statistics [26].

For the years since 2009, the emissions are calculated from the Belgian manufacturer’s sales in Belgium and for the emissions from use on the basis of the emissions per inhabitant estimated for Germany in [26]. These emissions are small compared with those of the nineties. Only two

types of foam are considered to still contain HFCs: high yield foam and fire protection foam (a third category – foam for underground coal mines – is not applicable in Belgium).

More recently, a consumption of HFC-134a and HFO-1234ze has been taking place for manufacturing canister foam, which is a type of one component foam produced in larger cans, typically for use on roofs. For this product HFC-134a is totally replaced by HFO-1234ze by 2019.

6.2.3 Foams in refrigerators/freezers

As for the previous years, emissions of CFC-11 have been evaluated from the estimated evolution of the stock of CFC-11, taking into account the recovery of CFC-11 from appliances at the end of their lifetime (see section 0).

6.2.4 Disposal emissions

The recovery or destruction of F-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.

6.3 Metered Dose Inhalers (MDI)

6.3.1 Emissions during production

Since 2006 there are no emissions anymore, the only manufacturer of MDIs in Belgium having stopped producing CFC or HFC containing products.

6.3.2 Emissions during use

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 Departement Omgeving [27]. The figures for 2018 were obtained by applying to those of 2017 the population growth.

Figure 23 below shows the development since 1995. Overall, after a stabilisation during the years 2012-2016, a small decline has been observed in 2017.

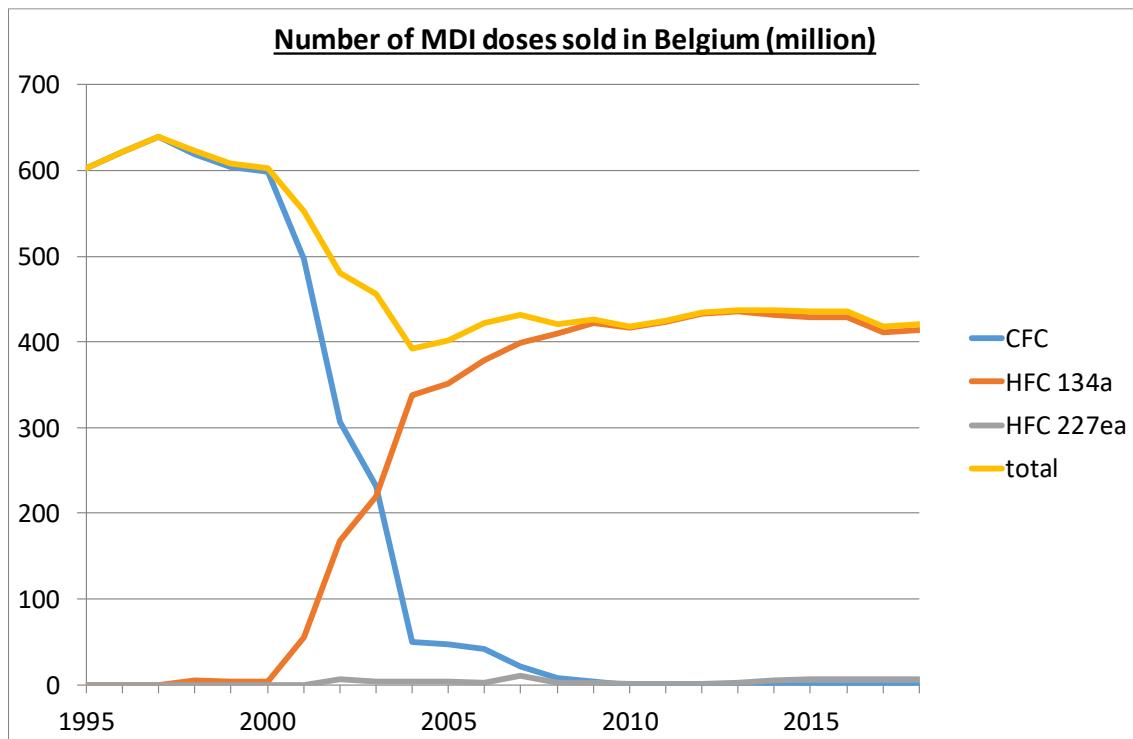


Figure 23: Number of MDI doses sold in Belgium (million)

The emissions, shown on Figure 24, have been estimated based on the type of gas used (found in the latest Compendium of pharmaceutical products, from pharma.be) and on assumptions on the quantity of F-gas per dose, taken from the literature.

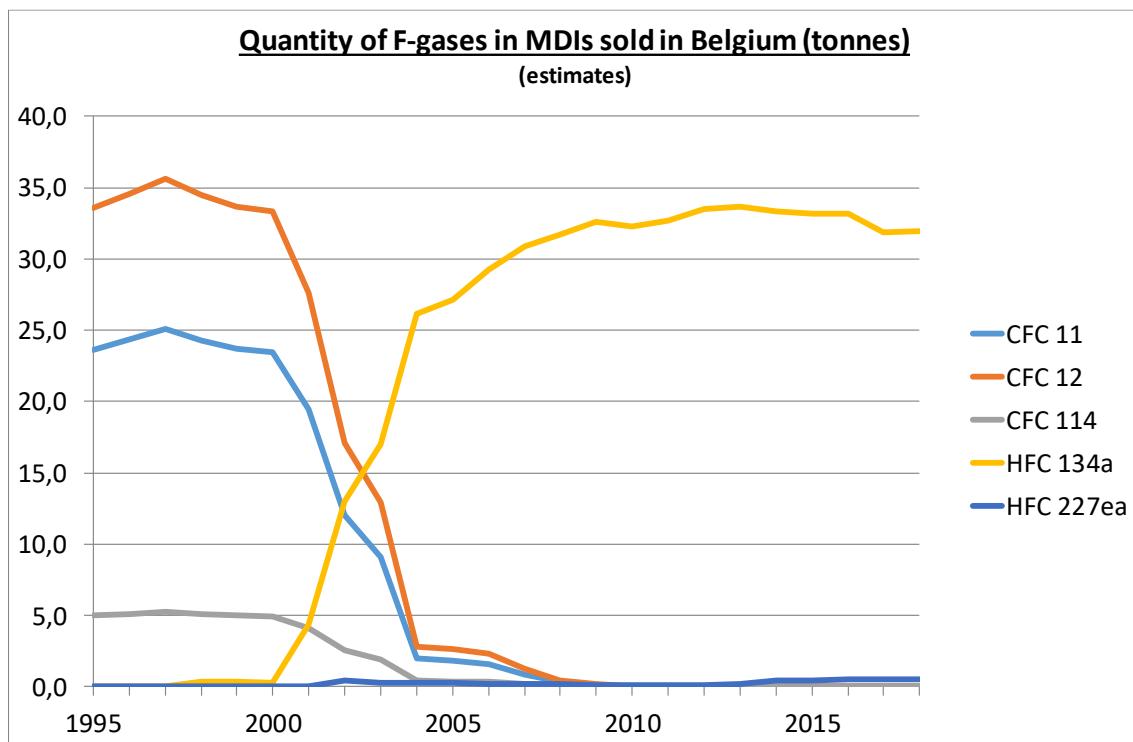


Figure 24: Quantity of F-gases in MDIs sold in Belgium (t)

In terms of greenhouse gas emissions, the evolution is shown on Figure 25. In 2017 the emissions declined from 49,0 to 47,2 kt CO₂-eq.

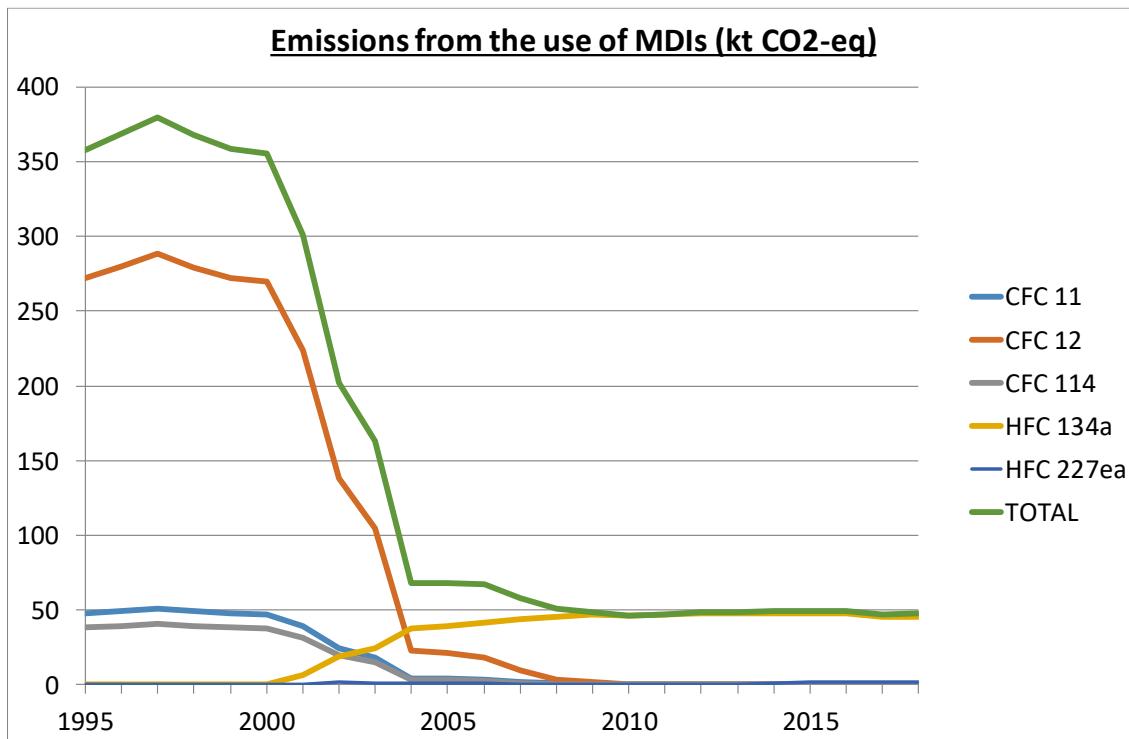


Figure 25: Emissions from the use of MDIs (kt CO₂-eq)

6.4 Technical aerosols

6.4.1 Emissions from manufacturing

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 companies (some did not want to disclose information due to confidentiality). We therefore used information from the Flemish IMJVs¹⁴ for 2018, which was split between HFC-134a and HFC-152a. Reporting is now limited to one company 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.

¹⁴ IMVJ: Integraal Milieu Jaarverslag.

6.4.2 Emissions from use

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 2017. 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 2,01 g/person in 2017. For 2018, the same emission factor as for 2017 is assumed.

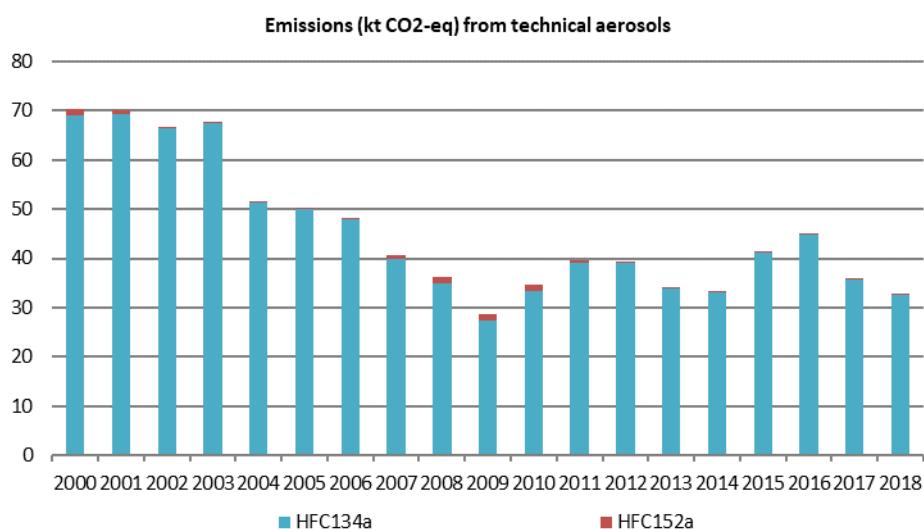


Figure 26: Emissions from the use of technical aerosols (kt CO2-eq.)

6.5 Fire extinguishing

A questionnaire has been sent to all relevant companies. Manufacturing emissions are estimated to be 0,1% for all quantities installed in bulk.

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.

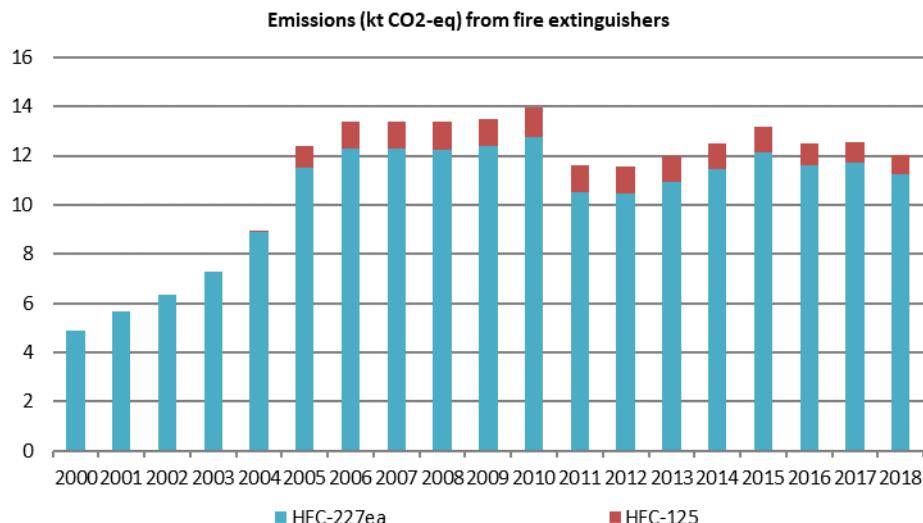


Figure 27: CRF-gas emissions from fire extinguishers (kt CO₂-eq.)

6.6 Solvent uses

6.6.1 HCFC-141b

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.

6.6.2 Other solvents

Next to HCFC- 141b or C6F14, several other F-gases can be used in production processes such as the semiconductor, the liquid crystal display and the photovoltaic industries. See section 6.7 below.

6.7 Semiconductors

For the photovoltaic industry, manufacturers have been contacted for the emissions in 2018. Photovolttech reported in previous years that no F-gases were used in their production process. Semiconductor manufacturers also reported the quantities of F-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.

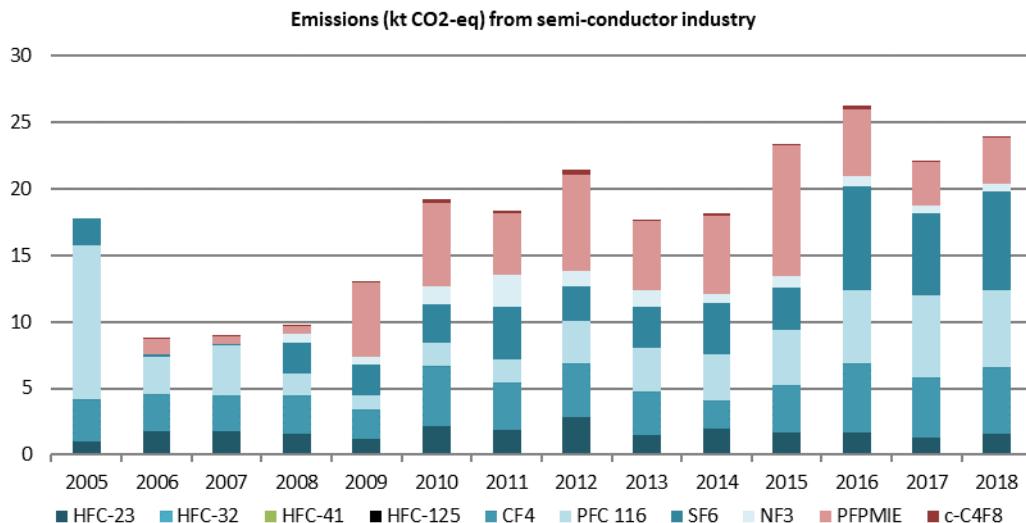


Figure 28: Emissions from semiconductor industry (in kt CO₂-eq)

6.8 Methylbromide

The emissions of methylbromide are presented on Figure 29.

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).

The evolution of emissions is shown on Figure 29. In 2018 these emissions reached 3,7 t.

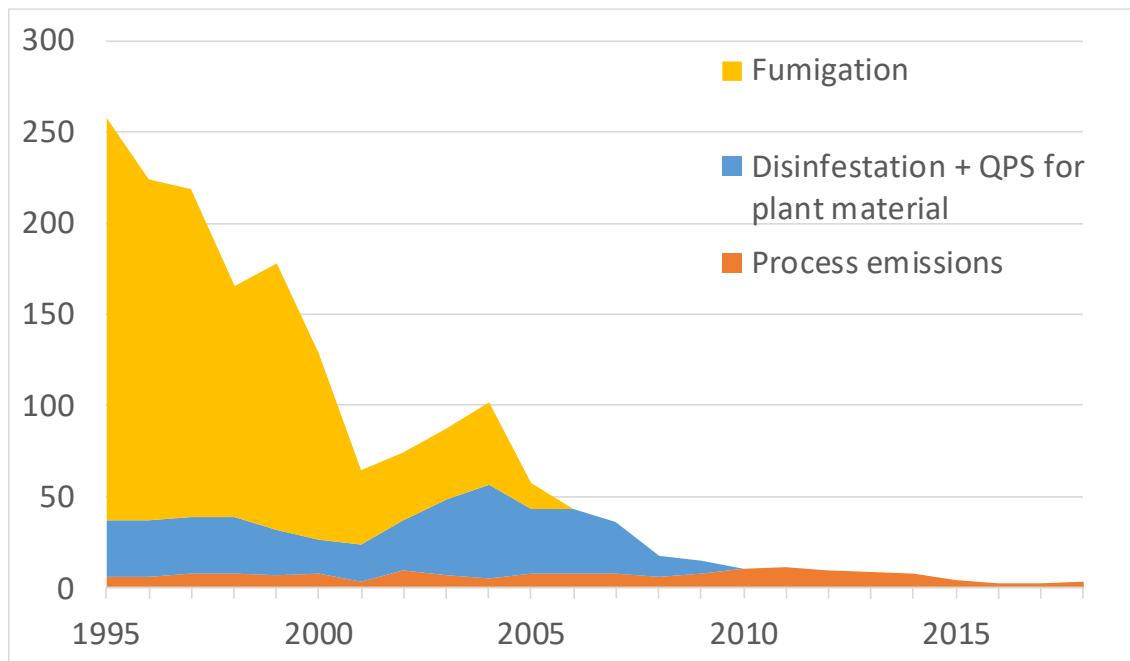


Figure 29: Emissions of methyl bromide (t)

6.9 SF₆

6.9.1 Glass sector

Regulation 842/2006/EC, replaced by EU Regulation 517/2014, 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. For the calculation of emissions, we used the IPCC 2006 guidelines.

Data on manufacturing emissions were calculated based on the consumption of SF₆ by glass producers and an annual emission factor of 33 %.

**EQUATION 8.20
DOUBLE-GLAZED WINDOWS: ASSEMBLY**

Assembly Emissions in year $t = 0.33 \cdot SF_6$ purchased to fill windows assembled in year t

**EQUATION 8.21
DOUBLE-GLAZED WINDOWS: USE**

Leakage Emissions in year $t = 0.01 \cdot$ Capacity of Existing Windows in year t

**EQUATION 8.22
DOUBLE-GLAZED WINDOWS: DISPOSAL**

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

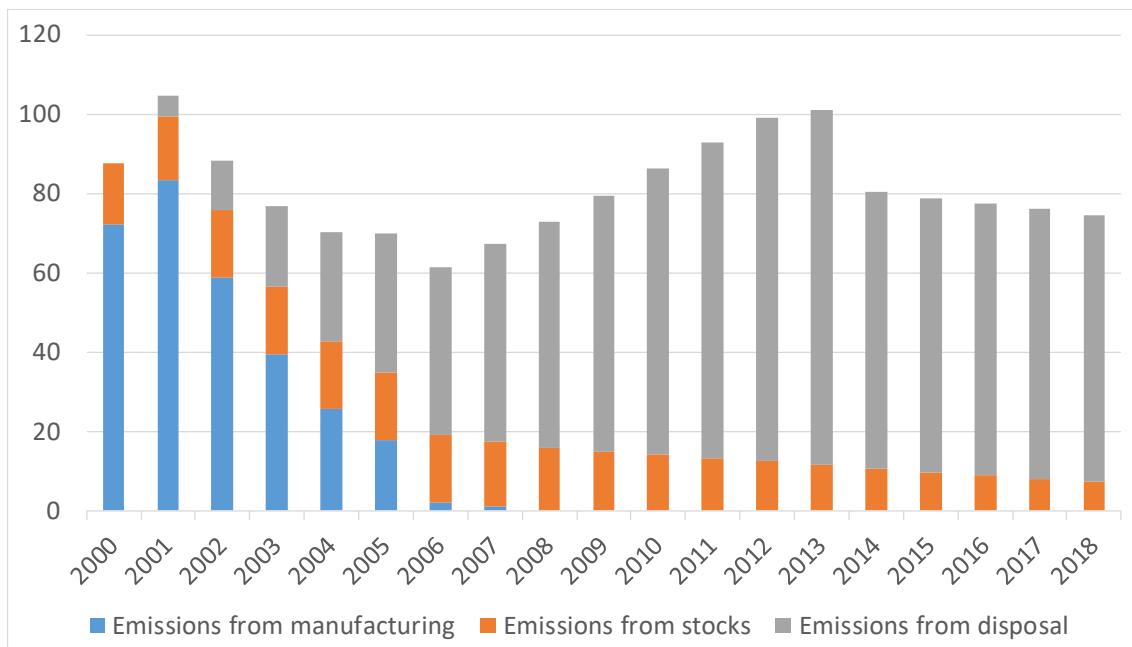


Figure 30. SF6 emissions from double glass in Belgium (in kt CO2-eq)

Since 2008, emissions from this sector only occur due to SF6 containing double glass that is replaced and decommissioned. To calculate fugitive emissions, we assume that 1 % of the SF6 bank, i.e. SF6 contained in installed double glazing in Belgium, is emitted annually.

To estimate disposal emissions, we assume a linear increase of disposal emissions with 0,32 t per year. The emissions in 2018 of SF6 from disposal were 2,95 t.

6.9.2 Electricity sector

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 1990-2000 is caused by new installations and that there is no disposal of SF6 in this period. An emission factor of 1% is used.

ELIA provided information on the use and emissions of SF6 in 2018. FEBEG reported the stock of SF6 in all large power stations in 2016 and the average quantity in switch gear in wind turbines, which was also used in 2017 and 2018 (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 stock of SF6 in MV switchgear at DNO's was adjusted from 2006 onwards to account for growth in use, although the impact on emissions is very low.

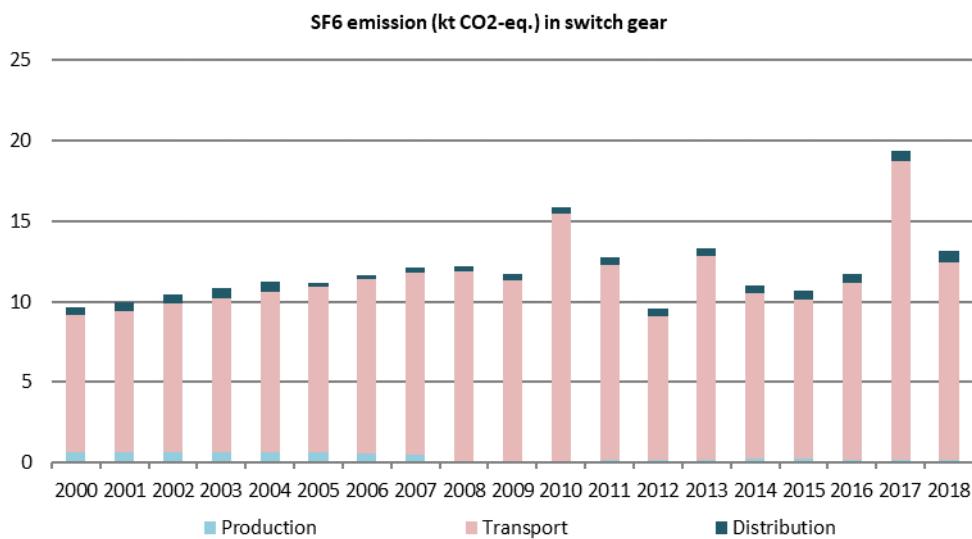


Figure 31. SF6 emissions (in kt CO2-eq) in switchgear in Belgium.

The fugitive 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 2017 and 2018¹⁵.

6.9.3 Sport Shoes

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.

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

¹⁵ 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%.

For the calculation of the disposal emissions from this source, we used the methodology and assumptions also used by Schwartz et al. (2003). Global data on SF6 use and data of the quantity of C3F8 placed on the EU market in sport soles are available. Schwartz et al. (2003) assumes that 35% 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.

6.9.4 Other sources of SF6

Particle accelerators

SF6 is used in elementary particle accelerators as an insulating gas. High-voltage particle accelerators (0,3 to more than 23 MV) are used in three different areas:

- Industrial applications in cross-linking polymers for cable insulation and for rubber parts and hoses
- Medical applications (radiotherapy)
- Research at universities and research institutions

This is not yet included in the emission inventory or in the sectoral calculations. To complete the inventory, we have estimated emissions to assess if they are sufficiently high to be included in the inventory in future.

In **industry**, high- and low-voltage devices are used. Gas losses occur at servicing, repair or adjustment of the device. Average annual emissions from industrial particle accelerators, range between 91 kg (high voltage) to 1,5 kg (low voltage), corresponding with 2 to 0,03 kt CO₂-eq. We do not have a complete overview of the number of industrial particle accelerators in Belgium. In the UK, the number of low voltage industrial particle accelerators was estimated to be 100 in 2012.

Linear accelerators for **medical radiotherapy** (cancer therapy) are industrially made and prefilled. Their waveguide is SF6 insulated and the filling volume is in the order of 3 litres – much smaller than most equipment in research and industry. In 2011, there were 25 recognized centres for radiotherapy in Belgium. These had a total of 96 accelerators in 2012 (22 less than 8 MeV and 74 more than 8 MeV). Using default IPCC emission factors (see tables below) this corresponds with an annual emission of 96 kg SF6 or 2,2 kt CO₂-eq.

TABLE 8.9
AVERAGE SF₆ CHARGE IN A PARTICLE ACCELERATOR BY PROCESS DESCRIPTION

Process Description	SF ₆ Charge Factor, kg
Industrial Particle Accelerators – high voltage (0.3-23 MV)	1300
Industrial Particle Accelerators – low voltage (<0.3 MV)	115
Medical (Radiotherapy)	0.5 ^a

^a This is the average of values ranging from 0.05 kg to over 0.8 kg, depending on model and manufacturer.
Source: Schwarz (2005)

TABLE 8.10 EMISSION FACTOR FOR EACH PROCESS DESCRIPTION, (SF ₆ EMISSIONS FROM INDUSTRIAL AND MEDICAL PARTICLE ACCELERATORS)	
Process Description	Emission Factor, kg /kg SF ₆ charge
Industrial Particle Accelerators – high voltage (0.3-23 MV)	0.07
Industrial Particle Accelerators – low voltage (<0.3 MV)	0.013
Medical (Radiotherapy)	2.0 ^a

^a This emission factor is the average of values ranging from 1 kg to 10 kg per kg charge, depending on model, manufacturer, and service intervals.

Source: Schwarz (2005)

To estimate the emissions of **research particle accelerators**, IPCC tier 1 method was used for a first assessment. This involves multiplying the number of particle accelerators with the average load (2,4 t), the SF₆ use factor (33%) and the emission factor (7%). This means an annual average emission of 55 kg or 1,3 kt CO₂-eq per research particle accelerator. According to http://www-elsa.physik.uni-bonn.de/accelerator_list.html there is only one institute in Belgium with scientific particle accelerators, the UCL, which has three different particle accelerators (cyclotrons). There are however several other universities and research centres that operate linear particle accelerators. Using Tier 1 methodology of the IPCC, this would mean an estimated emission of around 8,8 kt CO₂-eq (assuming 33% SF₆ use).

Particle accelerators are not reported by all EU countries and only some EU countries have included it in their emission inventory. Germany and France reported respectively 4,1 t and 3,3 t SF₆ emissions from particle accelerators, which is only marginally higher than our estimate on a per capita basis (50 kg SF₆ per capita versus 44 kg per capita). Emissions from this source in the UK (3,4 kg SF₆ per capita) are on the other hand much lower.

6.10 Chemical industry

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 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 CF₄-emissions nevertheless still occur. These are determined through measurements.

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 non-CRF-gases, from 2005 onwards by substance, in t and kt CO₂ equivalent.

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 insights.

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.

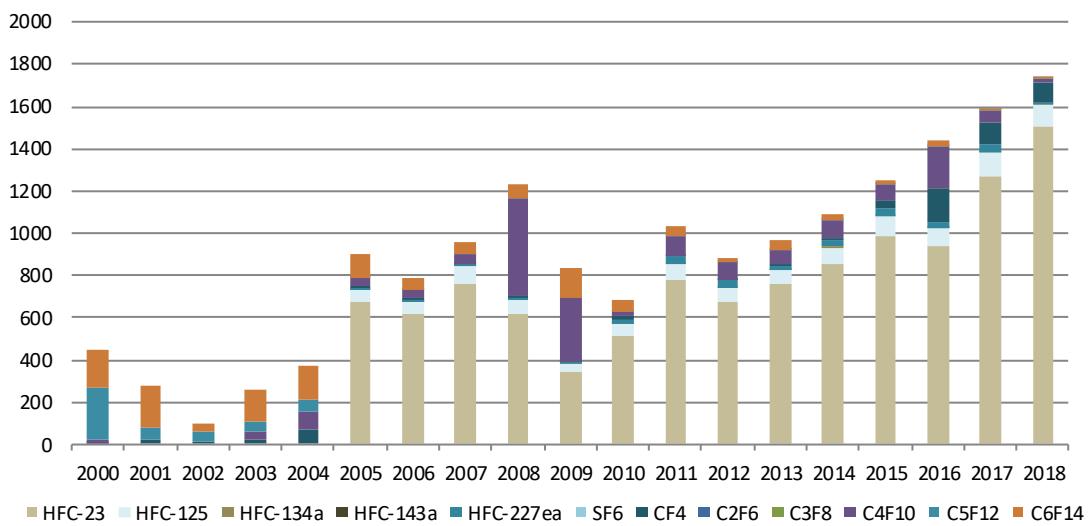
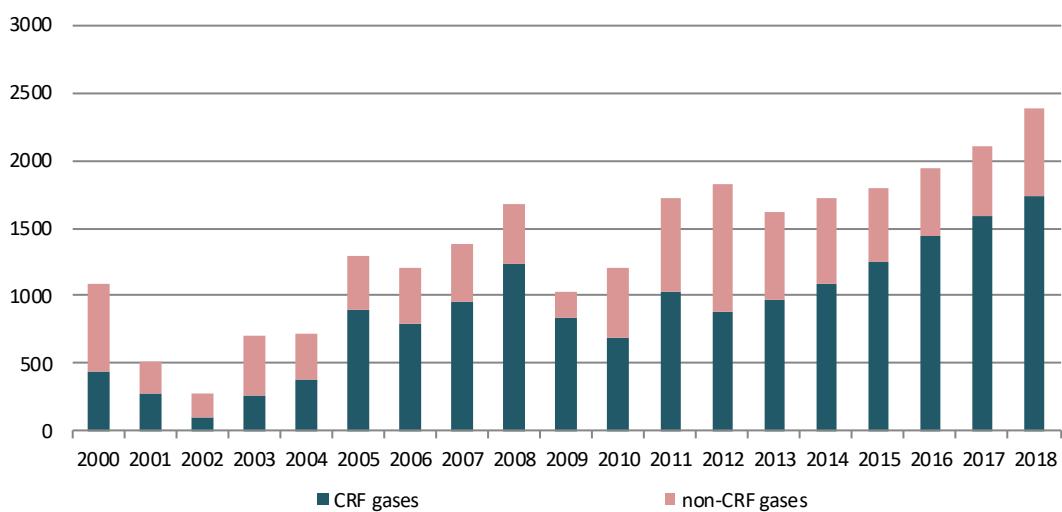
The drafting of the monitoring plan was performed in 2019. During that process, the company was assisted by an independent verification office (VBBV), appointed for that specific purpose by the Flemish Government because of its experience in monitoring EU ETS emissions. Its assessments resulted inter 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 CO₂-eq compared to the previous inventory, especially for the CRF-gases (1591 kt CO₂-eq instead of 155 kt CO₂-eq for the CRF-gases and 2103 kt CO₂-eq instead of 1031 kt CO₂-eq for the total emissions, in 2017), 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 32 and Figure 33.

The company is taking further measures to monitor emissions more intensively and is planning and implementing mitigation measures to substantially reduce emissions in the short term (2020-2021).

Figure 32: CRF-gas emissions from chemical industry (in kt CO₂-eq)Figure 33: Total emissions from chemical industry (in kt CO₂-eq)

7 OVERALL RESULTS

These results are presented below for the base year for F-gases in the Kyoto protocol (1995) and for the most recent year (2018), for Belgium and for each of the 3 regions, in tonnes, in kt CO₂-eq and in t CFC-eq (the latter for the ozone depleting substances (ODS)).

The substances are grouped by type (CFCs, HCFCs, Halons, HFCs, PFCs, SF₆, NF₃, HFOs and Other), and further grouped into three categories:

- ODS (Ozone depleting substances),
- CRF (substances for which there is a reporting obligation in the CRF format),
- Other.

FLANDERS 1995 (tonnes)	Refrigeration & air conditioning	Foams	Fire protection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
ODS	844,8	1.098,6	7,2	43,2	29,0			276,5	2.299,2
CFC	354,0	259,0		43,2					656,2
CFC-11	33,2	201,6		17,3					252,0
CFC-12	282,3	57,4		23,0					362,7
CFC-114				2,9					2,9
CFC-115	38,5								38,5
HCFC	490,9	839,5			29,0				1.359,3
HCFC-22	490,9	395,0							885,9
HCFC-141b		217,1			29,0				246,1
HCFC-142b		227,4							227,4
Halons			7,2						7,2
Halon 1211			1,0						1,0
Halon 1301			6,3						6,3
Other ODS								276,5	276,5
CCl4								28,0	28,0
CH3Br								248,4	248,4
CRF	35,6	149,1	0,1	17,0		397,7		3,4	602,9
HFC	35,6	149,1	0,1	17,0					201,7
HFC-125	0,9								0,9
HFC-134a	33,6	148,8		16,8					199,1
HFC-143a	1,0								1,0
HFC-152a		0,3		0,2					0,5
HFC-227ea			0,1						0,1
HFC-245fa		0,0							0,0
HFC-32	0,1								0,1
PFC						309,8			309,8
C2F6 (PFC-116)						71,8			71,8
C3F8 (PFC-218)						33,4			33,4
C4F10						41,8			41,8
C5F12						60,6			60,6
C6F14						32,9			32,9
CF4						69,2			69,2
SF6						88,0		3,4	91,4
Other						258,2			258,2
PFC						96,3			96,3
C7F16						23,9			23,9
C8F18						72,5			72,5
Other						161,9			161,9
C8F16O						71,0			71,0
CF3SF5						90,9			90,9
General total	880,4	1.247,7	7,3	60,2	29,0	655,9	0,0	279,9	3.160,3

7.3 Emissions in kt CO₂-eq in 2018

BELGIUM 2018 (kt CO ₂ -eq)	Refrigeration & air conditioning	Foams	Fire pro- tection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
ODS	42,1	779,7	-73,2					-4,6	744,0
CFC	0,1	519,9							520,0
CFC-11	0,0	101,7							101,7
CFC-12	0,1	418,2							418,2
HCFC	42,0	259,8							301,8
HCFC-22	41,6								41,6
HCFC-124	0,1								0,1
HCFC-141b		5,1							5,1
HCFC-142b	0,2	254,7							254,9
Halons			-73,2						-73,2
Halon 1211			-2,5						-2,5
Halon 1301			-70,8						-70,8
Other ODS							-4,6	-4,6	
CH3Br								-4,6	-4,6
CRF	2.702,3	54,1	12,0	80,1		1.740,0	20,7	87,7	4.696,9
HFC	2.702,3	54,1	12,0	80,1		1.619,6	1,7		4.469,8
HFC-125	884,2		0,8			102,2	0,1		987,3
HFC-134a	959,8	26,2		78,3		0,0			1.064,4
HFC-143a	810,9								810,9
HFC-152a	0,0	16,0		0,1					16,1
HFC-227ea		4,2	11,2	1,7		11,1			28,2
HFC-23						1.506,2	1,6		1.507,8
HFC-245fa			0,5						0,5
HFC-32		47,4					0,0		47,5
HFC-365mfc			7,2						7,2
HFC-41							0,0		0,0
PFC	0,0					120,4	10,9		131,3
C2F6 (PFC-116)							5,8		5,8
C3F8 (PFC-218)	0,0								0,0
C4F10						25,2			25,2
C5F12						0,0			0,0
C6F14						5,6			5,6
c-C4F8							0,1		0,1
CF4						89,6	5,0		94,6
SF6							7,4	87,7	95,1
NF3							0,6		0,6
Other	0,2	0,1				643,8	3,4		647,7
PFC						0,0			0,0
C7F16						0,0			0,0
HFO	0,2	0,1							0,4
R-1234yf	0,2								0,2
R-1234ze	0,0	0,1							0,1
Other						643,8	3,4		647,3
PFPMIE							3,4		3,4
Unspecified mix						643,8			643,8
General total	2.744,6	833,9	-61,2	80,1	0,0	2.383,8	24,1	83,1	6.088,5

FLANDERS 2018 (kt CO2-eq)	Refrigeration & air conditioning	Foams	Fire pro- tection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
ODS	24,2	449,1	-42,2					-4,6	426,6
CFC	0,1	299,5							299,5
CFC-11	0,0	58,6							58,6
CFC-12	0,0	240,9							240,9
HCFC	24,2	149,7							173,8
HCFC-22	24,0								24,0
HCFC-124	0,1								0,1
HCFC-141b		2,9							2,9
HCFC-142b	0,1	146,7							146,9
Halons			-42,2						-42,2
Halon 1211			-1,4						-1,4
Halon 1301			-40,8						-40,8
Other ODS							-4,6	-4,6	
CH3Br								-4,6	-4,6
CRF	1.567,6	41,5	6,9	46,2		1.740,0	20,7	51,1	3.474,0
HFC	1.567,6	41,5	6,9	46,2		1.619,6	1,7		3.283,5
HFC-125	511,4		0,5			102,2	0,1		614,2
HFC-134a	559,5	15,4		45,1		0,0			620,0
HFC-143a	469,3								469,3
HFC-152a	0,0	15,9		0,1					16,0
HFC-227ea		3,7	6,5	1,0		11,1			22,2
HFC-23						1.506,2	1,6		1.507,8
HFC-245fa			0,2						0,2
HFC-32		27,4					0,0		27,4
HFC-365mfc			6,3						6,3
HFC-41							0,0		0,0
PFC	0,0					120,4	10,9		131,3
C2F6 (PFC-116)							5,8		5,8
C3F8 (PFC-218)	0,0								0,0
C4F10						25,2			25,2
C5F12						0,0			0,0
C6F14						5,6			5,6
c-C4F8							0,1		0,1
CF4						89,6	5,0		94,6
SF6							7,4	51,1	58,5
NF3							0,6		0,6
Other	0,1	0,1				643,8	3,4		647,5
PFC						0,0			0,0
C7F16						0,0			0,0
HFO	0,1	0,1							0,2
R-1234yf	0,1								0,1
R-1234ze	0,0	0,1							0,1
Other						643,8	3,4		647,3
PFPMIE							3,4		3,4
Unspecified mix						643,8			643,8
General total	1.592,0	490,7	-35,3	46,2	0,0	2.383,8	24,1	46,5	4.548,1

7.4 Emissions in kt CO₂-eq in 1995

BELGIUM 1995 (kt CO ₂ -eq)	Refrigeration & air conditioning	Foams	Fire pro- tection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
ODS	5.935,6	4.185,7	-441,1	394,4	26,1	0,0	0,0	-333,0	9.767,7
CFC	4.551,7	1.498,2	0,0	394,4	0,0	0,0	0,0	0,0	6.444,3
CFC-11	115,7	694,7	0,0	55,0	0,0	0,0	0,0	0,0	865,3
CFC-12	3.940,4	803,5		301,2					5.045,1
CFC-114				38,2					38,2
CFC-115	495,7								495,7
HCFC	1.383,9	2.687,5			26,1				4.097,5
HCFC-22	1.383,9	1.685,3							3.069,1
HCFC-141b		114,3			26,1				140,4
HCFC-142b		887,9							887,9
Halons			-441,1						-441,1
Halon 1211			-28,5						-28,5
Halon 1301			-412,7						-412,7
Other ODS								-333,0	-333,0
CCl4								-11,1	-11,1
CH3Br								-321,9	-321,9
CRF	92,6	356,8	0,6	41,5		4.919,6		134,7	5.545,7
HFC	92,6	356,8	0,6	41,5					491,4
HFC-125	5,3								5,3
HFC-134a	79,9	356,7		41,4					478,1
HFC-143a	7,2								7,2
HFC-152a		0,1		0,0					0,1
HFC-227ea			0,6						0,6
HFC-245fa		0,0							0,0
HFC-32	0,1								0,1
PFC					2.914,3				2.914,3
C2F6 (PFC-116)					875,9				875,9
C3F8 (PFC-218)					294,5				294,5
C4F10					370,6				370,6
C5F12					555,5				555,5
C6F14					306,1				306,1
CF4					511,7				511,7
SF6					2.005,3		134,7	2.140,0	
Other					3.012,0				3.012,0
PFC					763,5				763,5
C7F16					183,8				183,8
C8F18					579,6				579,6
Other					2.248,5				2.248,5
C8F16O					667,1				667,1
CF3SF5					1.581,5				1.581,5
General total	6.028,2	4.542,5	-440,5	435,8	26,1	7.931,6	0,0	-198,3	18.325,4

FLANDERS 1995 (kt CO2-eq)	Refrigeration & air conditioning	Foams	Fire pro- tection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
ODS	3.456,1	2.057,8	-255,4	243,7	15,1			-320,7	5.196,5
CFC	2.640,3	872,5		243,7					3.756,5
CFC-11	67,0	407,2		34,9					509,1
CFC-12	2.286,2	465,3		186,7					2.938,2
CFC-114				22,1					22,1
CFC-115	287,0								287,0
HCFC	815,8	1.185,3			15,1				2.016,2
HCFC-22	815,8	656,5							1.472,3
HCFC-141b		113,1			15,1				128,2
HCFC-142b		415,7							415,7
Halons			-255,4						-255,4
Halon 1211			-16,5						-16,5
Halon 1301			-239,0						-239,0
Other ODS								-320,7	-320,7
CCl4								-10,7	-10,7
CH3Br								-310,0	-310,0
CRF	55,7	212,8	0,3	24,0		4.919,6		77,8	5.290,2
HFC	55,7	212,8	0,3	24,0					292,8
HFC-125	3,2								3,2
HFC-134a	48,1	212,7		24,0					284,8
HFC-143a	4,4								4,4
HFC-152a		0,0		0,0					0,1
HFC-227ea			0,3						0,3
HFC-245fa		0,0							0,0
HFC-32	0,1								0,1
PFC						2.914,3			2.914,3
C2F6 (PFC-116)						875,9			875,9
C3F8 (PFC-218)						294,5			294,5
C4F10						370,6			370,6
C5F12						555,5			555,5
C6F14						306,1			306,1
CF4						511,7			511,7
SF6						2.005,3		77,8	2.083,1
Other						3.012,0			3.012,0
PFC						763,5			763,5
C7F16						183,8			183,8
C8F18						579,6			579,6
Other						2.248,5			2.248,5
C8F16O						667,1			667,1
CF3SF5						1.581,5			1.581,5
General total	3.511,7	2.270,6	-255,1	267,7	15,1	7.931,6	0,0	-242,9	13.498,7

BRUSSELS 2018 (t CFC11-eq)	Refrigeration & air conditioning	Foams	Fire pro- tection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
CFC	0,00	10,75							10,75
CFC-11	0,00	5,31							5,31
CFC-12	0,00	5,44							5,44
HCFC	0,15	1,07							1,21
HCFC-22	0,15								0,15
HCFC-124	0,00								0,00
HCFC-141b		0,11							0,11
HCFC-142b	0,00	0,95							0,96
Halons			2,00						2,00
Halon 1211			0,05						0,05
Halon 1301			1,95						1,95
General total	0,15	11,81	2,00	0,00	0,00	0,00	0,00	0,03	13,96

BRUSSELS 1995 (t CFC11-eq)	Refrigeration & air conditioning	Foams	Fire pro- tection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
CFC	54,78	40,79		5,84					101,42
CFC-11	5,38	31,48		2,22					39,07
CFC-12	45,65	9,32		3,15					58,13
CFC-114				0,47					0,47
CFC-115	3,75								3,75
HCFC	4,19	0,43			0,52				5,14
HCFC-22	4,19								4,19
HCFC-141b		0,02			0,52				0,54
HCFC-142b		0,41							0,41
Halons			10,61						10,61
Halon 1211			0,46						0,46
Halon 1301			10,14						10,14
Other ODS								0,29	0,29
CCl4								0,13	0,13
CH3Br								0,16	0,16
General total	58,98	41,22	10,61	5,84	0,52	0,00	0,00	0,29	117,46

7.7 Emission evolution in Belgium

7.7.1 Evolution of emissions by gas

Figure 34 shows the evolution of the emissions in tonnes, in Belgium, by category of gas. The generally downward trend is slowly continuing.

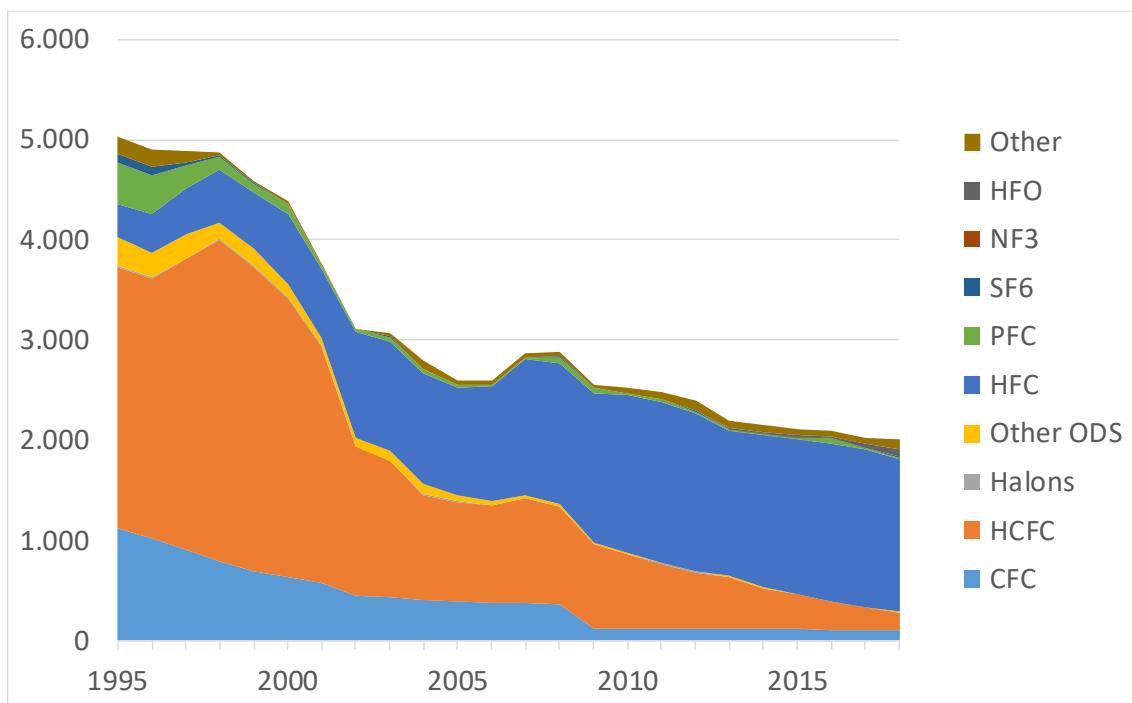


Figure 34: Evolution of the F-gas emissions by type of gas in Belgium (tonnes)

Figure 35 shows that up to 2008 the main substance in tonnes used to be HCFC-22, later it became HFC-134a.

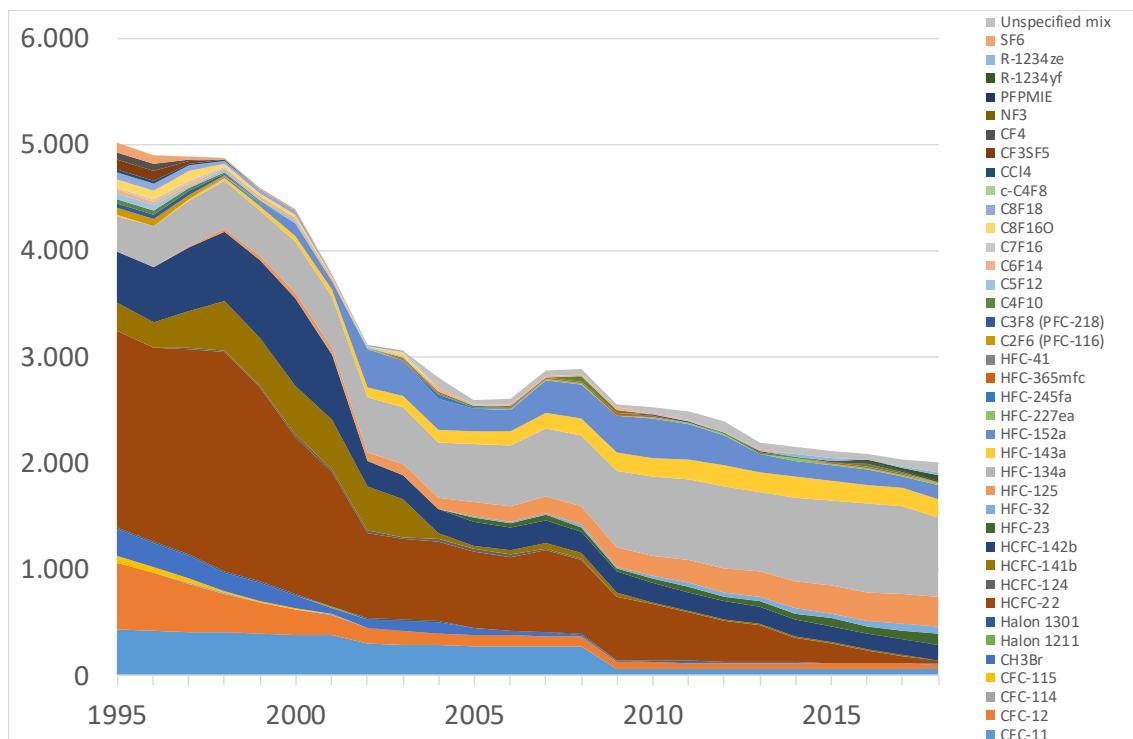


Figure 35: Evolution of the F-gas emissions by substance in Belgium (tonnes)

In terms of CO₂ equivalent, the emissions of the 'CRF-gases' (the gases of the Kyoto Protocol) are still regularly increasing (Figure 36).

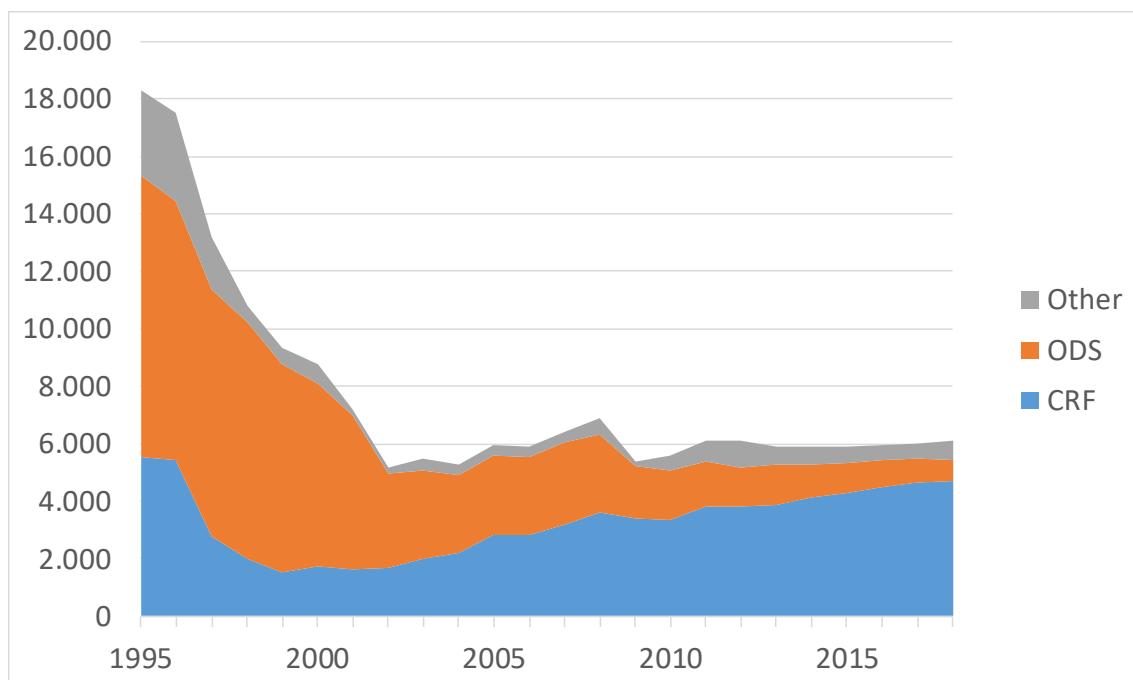


Figure 36: Evolution of the F-gas emissions per gas category in Belgium (kt CO₂-eq)

Figure 37 shows that the bulk of CRF-gas emissions is from HFCs.

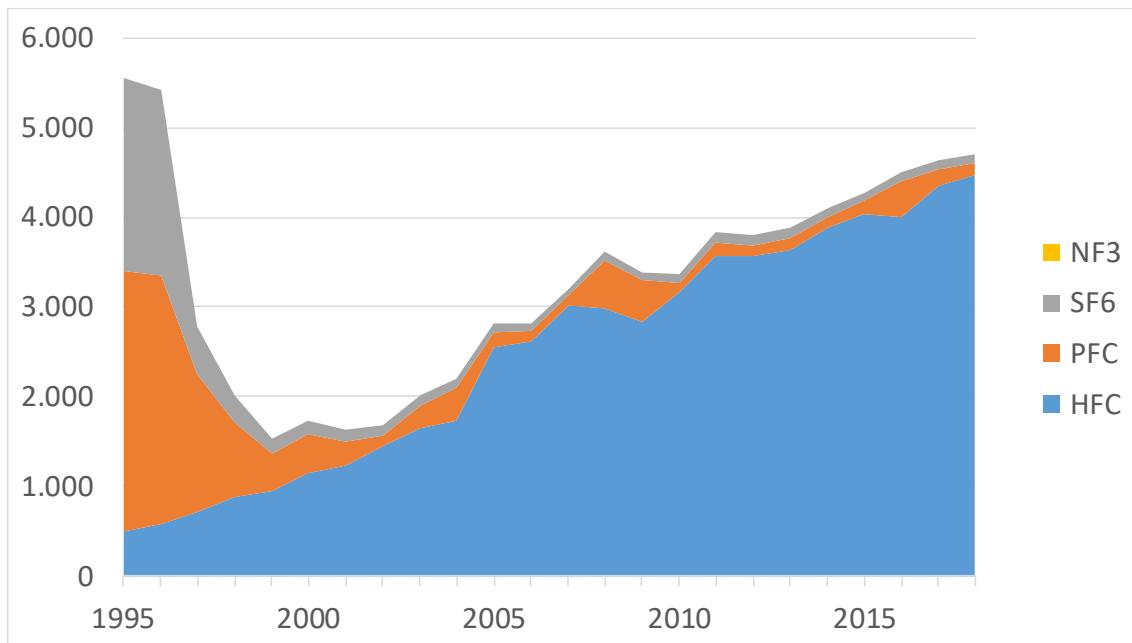


Figure 37: Evolution of the Kyoto F-gas emissions per gas category in Belgium (kt CO2-eq)

On Figure 38, notable is the predominance of HFCs R23 (from the chemical industry), R143a, R134a and R125 in the last decade.

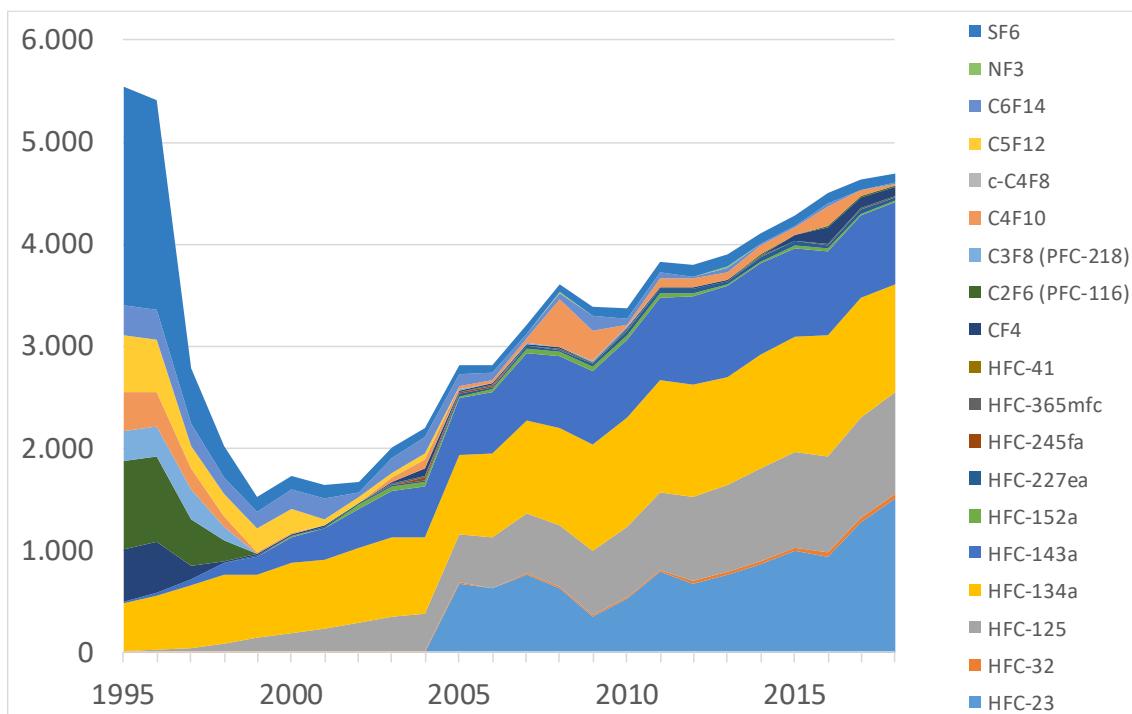


Figure 38: Evolution of the Kyoto F-gas emissions per substance in Belgium (kt CO2-eq)

The corresponding values are given in Table 19 (in tonnes) and Table 20 (in kt CO2-eq).

Table 19: Evolution of emissions by substance in Belgium, in tonnes

(tonnes)	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018
ODS	4.024,2	3.553,6	1.443,3	870,1	693,2	644,5	524,8	463,4	390,7	332,6	282,2
CFC	1.122,8	625,8	380,0	118,1	113,6	111,6	109,5	107,5	105,6	103,8	102,0
CFC-11	428,4	379,0	269,5	53,1	52,3	52,0	51,6	51,3	51,0	50,7	50,4
CFC-12	622,9	236,9	110,1	65,0	61,3	59,6	57,9	56,2	54,7	53,1	51,6
CFC-114	5,0	4,9	0,4	0,0	0,0						
CFC-115	66,6	4,9									
HCFC	2.601,9	2.786,4	998,7	736,4	564,9	521,0	404,7	349,4	280,9	224,0	174,6
HCFC-22	1.846,7	1.480,4	726,2	535,8	380,8	343,5	234,3	184,4	121,7	69,7	25,1
HCFC-124		19,1	16,8	6,4	3,0	2,3	1,1	0,9	0,4	0,3	0,2
HCFC-141b	269,5	454,7	36,1	10,3	10,2	10,1	10,1	10,0	9,9	9,9	9,8
HCFC-142b	485,7	832,2	219,6	183,9	170,9	165,1	159,2	154,1	148,9	144,1	139,5
Halons	12,5	12,5	6,6	4,2	4,9	2,6	2,5	2,6	2,0	2,0	2,0
Halon 1211	1,7	1,7	0,7	0,2	0,2	0,2	0,2	0,2	0,1	0,1	0,1
Halon 1301	10,8	10,8	5,9	4,0	4,7	2,5	2,3	2,4	1,8	1,8	1,9
Other ODS	287,1	129,0	58,0	11,3	9,8	9,3	8,2	4,0	2,1	2,9	3,7
CCl4	29,2	0,7	0,7	0,7	0,7	0,7					
CH3Br	257,9	128,3	57,3	10,6	9,1	8,7	7,5	4,0	2,1	2,9	3,7
CRF	742,2	760,4	1.108,7	1.597,5	1.596,8	1.465,4	1.538,6	1.557,7	1.629,0	1.595,0	1.549,1
HFC	338,6	705,4	1.085,8	1.581,0	1.578,9	1.445,2	1.519,9	1.536,5	1.575,9	1.568,2	1.528,1
HFC-23			45,6	35,1	45,5	51,4	57,6	67,0	63,4	85,9	101,9
HFC-32	0,1	3,7	9,4	26,6	34,7	39,8	46,5	51,0	58,6	67,5	70,3
HFC-41				0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
HFC-125	1,5	52,6	133,8	195,3	233,2	243,3	260,2	265,6	266,0	280,6	282,1
HFC-134a	334,3	479,6	545,0	750,2	774,5	739,2	779,7	792,0	832,2	823,2	744,3
HFC-143a	1,6	55,6	124,2	172,6	193,5	199,0	201,4	195,8	186,4	179,2	181,4
HFC-152a	0,8	112,4	205,3	370,0	280,9	161,3	154,5	140,8	145,9	100,2	129,8
HFC-227ea	0,2	1,5	7,1	10,7	13,7	9,4	14,2	15,2	13,1	17,3	8,8
HFC-245fa	0,0	0,1	10,6	0,6	0,9	0,8	0,8	0,8	0,7	0,5	0,5
HFC-365mfc			4,9	19,9	1,9	0,9	4,9	8,3	9,5	13,7	9,1
PFC	309,8	48,7	18,8	11,8	13,0	15,0	14,5	17,1	48,8	22,3	16,7
CF4	69,2	1,0	1,2	2,1	0,8	0,9	1,6	6,6	22,5	13,9	12,8
C2F6 (PFC-116)	71,8		1,0	0,1	0,3	0,3	0,3	0,3	0,5	0,5	0,5
C3F8 (PFC-218)	33,4	0,0	0,3	0,9	0,2	0,4	0,3		0,0	0,0	0,0
C4F10	41,8	2,0	3,9	2,6	9,8	7,5	9,5	7,7	22,7	7,2	2,8
c-C4F8				0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
C5F12	60,6	26,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
C6F14	32,9	19,2	12,5	6,0	1,9	5,9	2,9	2,5	3,2	0,6	0,6
SF6	93,9	6,3	4,0	4,6	4,9	5,1	4,2	4,1	4,3	4,5	4,2
NF3				0,1	0,1	0,1	0,0	0,0	0,0	0,0	0,0
Other	258,2	75,4	42,9	57,2	102,8	79,1	91,0	87,4	71,0	99,2	168,8
PFC	96,3	49,7						0,0	0,0	0,0	0,0
C7F16	23,9	9,4						0,0	0,0	0,0	0,0
C8F18	72,5	40,4									
HFO						8,7	22,1	27,9	16,0	42,6	81,6
R-1234yf							0,3	1,6	10,3	31,8	58,3
R-1234ze						8,7	21,8	26,3	5,8	10,8	23,3
Other	161,9	25,6	42,9	57,2	102,8	70,3	68,9	59,5	54,9	56,6	87,2
C8F16O	71,0	25,6									
CF3SF5	90,9										
PFPMIE				0,6	0,7	0,5	0,6	1,0	0,5	0,3	0,4
Unspecified mix			42,9	56,5	102,1	69,8	68,3	58,5	54,4	56,3	86,8
General total	5.024,6	4.389,4	2.594,8	2.524,7	2.392,8	2.189,0	2.154,4	2.108,5	2.090,7	2.026,7	2.000,1

In 2018, the total emissions have diminished by 1,3%. For the CRF-gases, there is a corresponding decrease of 2,9%.

The evolution of emissions of ozone depleting substances, expressed in tonnes CFC-11 equivalent, is shown on Table 21, Figure 39 (by gas category) and Figure 40 (by substance). It can be remembered that the fall 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.

Table 21: Evolution of emissions of ozone depleting substances in Belgium, in t CFC11-eq

(t CFC-11 eq)	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018
CFC	1.096,15	623,79	379,98	118,14	113,63	111,55	109,49	107,55	105,63	103,79	102,00
CFC-11	428,39	379,02	269,54	53,11	52,30	51,97	51,61	51,30	50,98	50,67	50,36
CFC-114	4,98	4,94	0,39	0,00	0,00						
CFC-115	39,94	2,95									
CFC-12	622,85	236,88	110,05	65,03	61,33	59,59	57,87	56,25	54,66	53,12	51,63
HCFC	162,78	185,95	58,56	42,70	33,24	30,79	24,37	21,28	17,47	14,29	11,53
HCFC-124		0,42	0,37	0,14	0,07	0,05	0,02	0,02	0,01	0,01	0,01
HCFC-141b	29,64	50,01	3,97	1,13	1,12	1,11	1,11	1,10	1,09	1,08	1,08
HCFC-142b	31,57	54,09	14,27	11,96	11,11	10,73	10,35	10,02	9,68	9,37	9,07
HCFC-22	101,57	81,42	39,94	29,47	20,94	18,89	12,89	10,14	6,69	3,83	1,38
Halons	112,95	112,95	61,41	40,57	47,51	25,07	23,39	24,55	18,92	18,49	18,95
Halon 1211	4,95	4,95	2,14	0,71	0,60	0,53	0,52	0,50	0,45	0,44	0,43
Halon 1301	108,00	108,00	59,27	39,85	46,91	24,54	22,87	24,05	18,47	18,05	18,52
Other ODS	186,86	77,73	35,13	7,10	6,22	5,94	5,23	2,38	1,29	1,72	2,20
CCl4	32,10	0,74	0,74	0,74	0,74	0,74	0,74				
CH3Br	154,76	76,99	34,38	6,36	5,47	5,19	4,48	2,38	1,29	1,72	2,20
General total	1.558,74	1.000,42	535,07	208,51	200,60	173,35	162,47	155,76	143,31	138,29	134,67

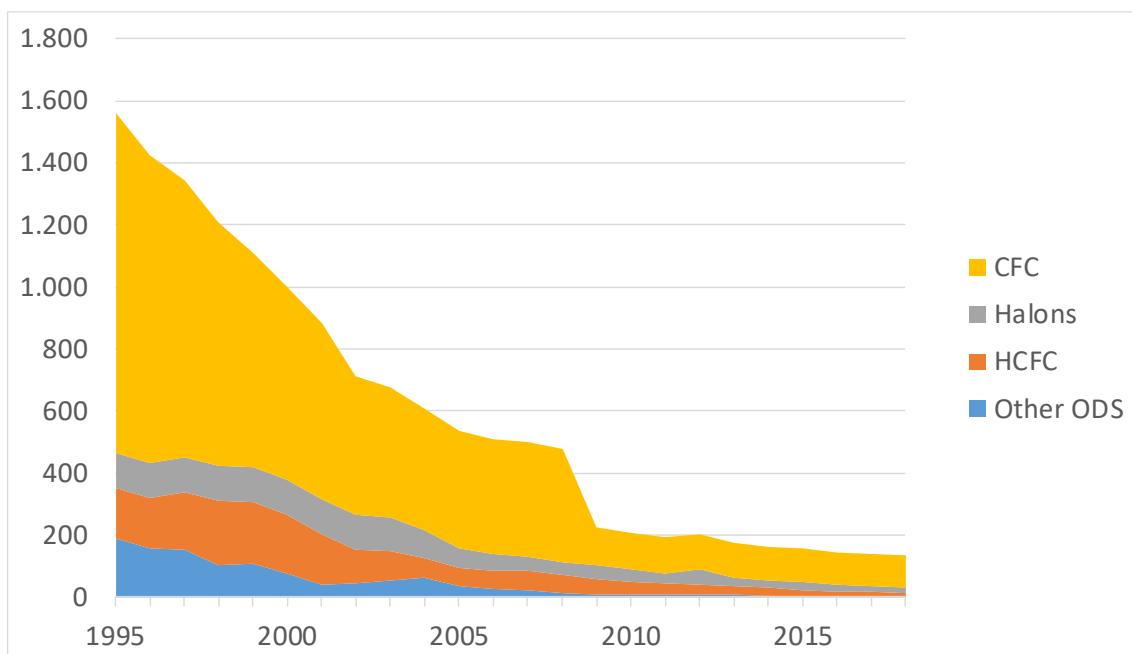


Figure 39: Evolution of ozone depleting substances, by gas category, in Belgium (t CFC11-eq)

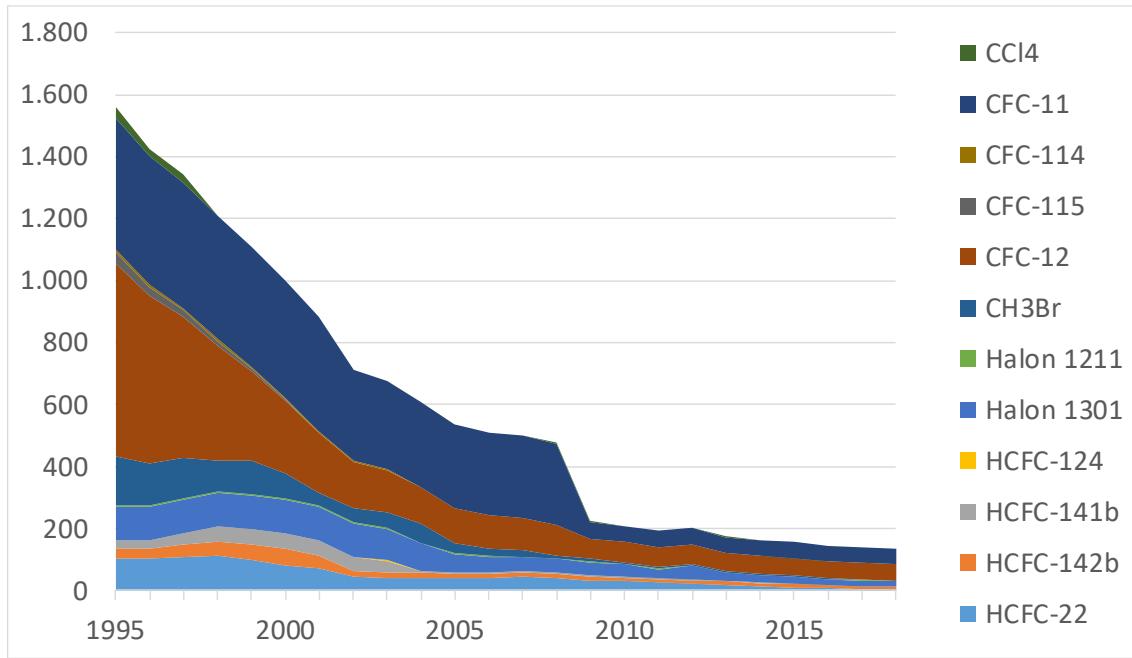


Figure 40: Evolution of ozone depleting substances, by substance, in Belgium (t CFC11-eq)

7.7.2 Evolution of emissions by source

The evolution by source is given in Table 22 in tonnes and Table 24 in kt CO₂-eq.

Table 22: Evolution of total emissions per source, in tonnes

(tonnes)	1995	2000	2005	2010	2015	2016	2017	2018
01. Dom. refrig. - Coolant	47,34	46,22	40,23	8,74	10,52	9,17	8,75	8,14
02. Dom. refrig. - Foam	286,08	282,10	210,76	0,42	0,38	0,30	0,35	0,34
03. Stationary airco	256,28	351,12	317,79	345,30	298,73	285,79	280,37	213,26
04. Car airco	28,58	67,10	144,82	242,47	271,48	275,84	284,41	298,48
05. Bus&Coach airco	8,06	7,82	8,81	11,12	13,00	13,41	13,70	14,08
06. Trucks airco		4,72	15,58	31,77	44,35	47,84	51,50	54,64
07. Refrigerated transport	0,44	3,37	8,37	13,12	11,44	9,26	6,50	6,70
08. Passenger rail transport		2,46	2,57	3,13	2,06	2,25	2,29	2,60
10. Ind.&comm. refrig.	1.161,42	990,92	924,24	923,45	721,39	699,34	674,42	661,76
11. Closed cell foam	1.876,23	1.806,06	603,40	704,39	454,62	442,91	394,80	407,49
12. PU cans	249,95	204,15	34,08	25,36	20,99	25,35	28,91	24,52
13. Aerosols MDI	69,39	66,48	32,35	32,41	33,66	33,65	32,35	32,50
14. Other aerosols	29,29	58,54	36,74	32,85	30,85	33,28	25,55	23,50
15. CCl4	29,18	0,68	0,68	0,68				
16. Methylbr.	257,93	128,32	57,30	10,60	3,97	2,14	2,86	3,66
17. SF6 electr. Sector	0,35	0,42	0,49	0,69	0,47	0,51	0,85	0,58
18. SF6 in glass sector	3,50	3,85	3,06	3,78	3,46	3,40	3,33	3,27
19. Fire Extinguishers	12,63	13,96	10,47	8,53	6,63	5,86	5,83	5,71
20. Chemical Ind	655,91	124,00	126,18	124,05	178,35	198,15	208,10	236,86
21. Semiconductors			1,53	1,85	2,16	2,21	1,88	2,06
22. Nike shoes	2,06	2,06	0,35					
23. Solvents	50,00	225,00	15,00					
Total	5.024,61	4.389,36	2.594,82	2.524,73	2.108,51	2.090,65	2.026,75	2.000,13

Stationary and mobile refrigeration and air conditioning are the main sources, together with closed cell foams. The total emission is declining by 26,6 t in 2018. Except for a minor change for semiconductors, the only source with rising emissions is 'Chemical ind'.

Table 23: Evolution of total emissions per source, in kt CO2-eq

(kt CO2-eq)	1995	2000	2005	2010	2015	2016	2017	2018
01. Dom. refriger. - Coolant	383,2	367,0	265,8	18,7	23,6	21,4	20,4	19,1
02. Dom. refriger. - Foam	577,9	569,8	425,6	0,4	0,4	0,3	0,4	0,4
03. Stationary airco	425,9	580,3	528,2	576,3	509,4	491,2	485,7	379,3
04. Car airco	133,7	96,0	207,1	346,7	386,1	381,5	368,2	358,6
05. Bus&Coach airco	53,5	11,2	12,6	15,9	18,6	19,2	19,6	20,1
06. Trucks airco	0,0	6,8	22,3	45,4	63,4	67,6	69,6	69,4
07. Refrigerated transport	1,5	10,6	26,6	41,3	36,8	30,0	21,0	21,5
08. Passenger rail transport	0,0	3,7	3,8	4,6	3,0	3,3	3,4	4,0
10. Ind.&comm. refriger.	5.030,5	2.314,0	2.011,4	2.212,4	2.013,5	1.940,8	1.879,2	1.872,7
11. Closed cell foam	3.607,9	3.357,5	1.188,7	1.082,6	910,5	890,8	859,5	830,3
12. PU cans	356,8	239,0	48,0	3,8	5,0	23,6	28,1	3,2
13. Aerosols MDI	394,4	378,7	67,9	46,6	49,0	49,0	47,2	47,4
14. Other aerosols	41,5	70,3	50,3	34,6	41,5	45,1	35,7	32,7
15. CCl4	-11,1	-0,3	-0,3	-0,3				
16. Methylbr.	-321,9	-160,1	-71,5	-13,2	-5,0	-2,7	-3,6	-4,6
17. SF6 electr. Sector	8,0	9,6	11,2	15,8	10,7	11,7	19,4	13,1
18. SF6 in glass sector	79,8	87,8	69,9	86,2	78,9	77,4	76,0	74,5
19. Fire Extinguishers	-440,5	-436,3	-226,3	-142,4	-81,6	-60,6	-58,9	-61,2
20. Chemical Ind	7.931,6	1.081,8	1.259,3	1.207,0	1.798,9	1.945,3	2.102,8	2.383,8
21. Semiconductors	0,0		17,8	19,4	23,4	26,2	22,2	24,1
22. Nike shoes	46,9	47,0	8,0					
23. Solvents	26,1	117,2	7,8					
Total	18.325,4	8.751,5	5.934,1	5.601,9	5.886,1	5.961,2	5.995,8	6.088,5

In tonnes CO2-eq, 'Chemical ind' becomes the largest emitter and its rising emissions more than compensate the decreases of the remaining sources. Overall emission increase by 92,7 kt CO2-eq in 2018.

Table 24: Evolution of CRF-gas emissions per source, in kt CO2-eq

(kt CO2-eq)	1995	2000	2005	2010	2015	2016	2017	2018
01. Dom. refriger. - Coolant	0,1	2,6	23,1	18,7	23,6	21,4	20,4	19,1
02. Dom. refriger. - Foam	0,0	0,1	0,1	0,4	0,4	0,3	0,4	0,4
03. Stationary airco	1,8	45,9	67,8	165,5	320,2	351,2	393,3	350,5
04. Car airco	21,0	96,0	207,1	346,7	386,1	381,5	368,0	358,4
05. Bus&Coach airco	2,5	11,2	12,6	15,9	18,6	19,2	19,6	20,1
06. Trucks airco		6,8	22,3	45,4	63,4	67,6	69,6	69,4
07. Refrigerated transport	1,5	10,6	26,6	41,3	36,8	30,0	21,0	21,5
08. Passenger rail transport		3,7	3,8	4,6	3,0	3,3	3,4	4,0
10. Ind.&comm. refriger.	65,7	619,9	1.216,5	1.721,5	1.894,7	1.877,9	1.855,2	1.859,4
11. Closed cell foam		29,0	74,1	115,2	65,5	68,2	58,7	50,6
12. PU cans	356,8	239,0	48,0	3,8	4,9	23,6	28,1	3,1
13. Aerosols MDI		0,4	39,7	46,5	49,0	49,0	47,2	47,4
14. Other aerosols	41,5	70,3	50,3	34,6	41,5	45,1	35,7	32,7
17. SF6 electr. Sector	8,0	9,6	11,2	15,8	10,7	11,7	19,4	13,1
18. SF6 in glass sector	79,8	87,8	69,9	86,2	78,9	77,4	76,0	74,5
19. Fire Extinguishers	0,6	4,9	12,4	14,0	13,1	12,5	12,6	12,0
20. Chemical Ind	4.919,6	445,9	900,2	684,1	1.250,6	1.440,7	1.590,8	1.740,0
21. Semiconductors			17,8	13,0	13,6	21,1	19,0	20,7
22. Nike shoes	46,9	47,0	8,0					
Total	5.545,7	1.730,5	2.811,4	3.373,4	4.274,6	4.501,8	4.638,2	4.696,9

As far as CRF-gases are concerned, there is an overall increase of 58,7 kt CO2-eq in 2018 (1,3%), the increase of 149,2 kt CO2-eq of 'Chemical ind' being compensated mainly by 'Stationary airco' (-42,9 kt CO2-eq) and 'PU cans' (-24,9 kt CO2-eq).

The corresponding tables for the three regions are given below.

Table 25: Evolution of CRF-gas emissions per source in Flanders, in kt CO2-eq

(kt CO2-eq)	1995	2000	2005	2010	2015	2016	2017	2018
01. Dom. refriger. - Coolant	0,0	1,5	13,4	10,9	13,4	12,1	11,7	10,7
02. Dom. refriger. - Foam	0,0	0,0	0,1	0,3	0,2	0,2	0,2	0,1
03. Stationary airco	1,1	40,4	42,5	96,8	185,1	202,6	226,7	202,2
04. Car airco	13,9	58,5	124,1	203,9	228,0	226,8	220,4	212,7
05. Bus&Coach airco	1,5	6,5	7,4	9,3	10,8	11,1	11,3	11,7
06. Trucks airco		3,9	13,1	26,4	36,6	39,1	40,2	40,1
07. Refrigerated transport	1,2	8,2	20,5	32,4	28,3	23,1	16,2	16,8
08. Passenger rail transport		2,2	2,2	2,7	1,7	1,9	2,0	2,3
10. Ind.&comm. refriger.	38,0	359,6	703,8	992,9	1.089,3	1.079,6	1.067,7	1.071,0
11. Closed cell foam		4,8	69,9	107,6	55,4	57,7	47,7	39,4
12. PU cans	212,8	139,2	30,0	2,4	3,1	14,2	17,0	2,0
13. Aerosols MDI		0,2	22,9	26,8	28,1	28,2	27,2	27,3
14. Other aerosols	24,0	51,0	32,3	23,5	25,4	27,9	21,9	18,9
17. SF6 electr. Sector	5,1	6,1	7,2	9,9	6,7	7,4	12,2	8,1
18. SF6 in glass sector	45,6	75,3	47,9	49,7	45,4	44,5	43,7	42,9
19. Fire Extinguishers	0,3	2,8	7,2	8,1	7,6	7,2	7,2	6,9
20. Chemical Ind	4.919,6	445,9	900,2	684,1	1.250,6	1.440,7	1.590,8	1.740,0
21. Semiconductors			17,8	13,0	13,6	21,1	19,0	20,7
22. Nike shoes	27,2	27,3	4,6					
Total	5.290,2	1.233,3	2.067,0	2.300,4	3.029,3	3.245,5	3.383,1	3.474,0

Table 26: Evolution of CRF-gas emissions per source in Wallonia, in kt CO2-eq

(kt CO2-eq)	1995	2000	2005	2010	2015	2016	2017	2018
01. Dom. refriger. - Coolant	0,0	0,8	7,5	6,1	7,9	7,1	6,7	6,4
02. Dom. refriger. - Foam	0,0	0,0	0,0	0,1	0,2	0,1	0,1	0,2
03. Stationary airco	0,6	4,3	19,5	52,4	101,7	111,8	125,3	111,4
04. Car airco	4,9	26,8	60,5	103,5	116,4	116,5	113,5	109,7
05. Bus&Coach airco	0,8	3,6	4,0	5,0	5,9	6,1	6,2	6,4
06. Trucks airco		2,2	7,1	14,5	20,2	21,5	22,1	22,0
07. Refrigerated transport	0,3	1,7	4,2	5,9	5,9	4,8	3,3	3,2
08. Passenger rail transport		1,2	1,2	1,5	1,0	1,1	1,1	1,3
10. Ind.&comm. refriger.	21,5	202,2	395,5	555,6	606,8	600,3	592,3	592,4
11. Closed cell foam		24,2	3,2	5,9	7,6	7,9	8,2	8,4
12. PU cans	112,6	78,3	14,9	1,1	1,4	7,0	8,3	0,8
13. Aerosols MDI		0,1	12,9	15,0	15,7	15,7	15,1	15,1
14. Other aerosols	13,6	15,0	13,9	8,5	12,2	13,0	10,4	10,4
17. SF6 electr. Sector	2,4	2,9	3,2	4,5	3,0	3,3	5,4	3,8
18. SF6 in glass sector	33,2	11,1	16,9	27,8	25,3	24,8	24,3	23,8
19. Fire Extinguishers	0,2	1,6	4,0	4,5	4,2	4,0	4,0	3,8
22. Nike shoes	15,3	15,3	2,6					
Total	205,3	391,3	571,4	811,9	935,2	944,8	946,2	919,1

Table 27: Evolution of CRF-gas emissions per source in Brussels-Capital region, in kt CO2-eq

(kt CO2-eq)	1995	2000	2005	2010	2015	2016	2017	2018
01. Dom. refriger. - Coolant	0,0	0,2	2,2	1,7	2,3	2,1	2,0	2,0
02. Dom. refriger. - Foam	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1
03. Stationary airco	0,2	1,2	5,8	16,3	33,3	36,9	41,3	36,8
04. Car airco	2,2	10,7	22,5	39,3	41,7	38,1	34,2	35,9
05. Bus&Coach airco	0,2	1,0	1,2	1,6	1,9	2,0	2,0	2,1
06. Trucks airco		0,6	2,1	4,5	6,6	7,0	7,3	7,3
07. Refrigerated transport	0,1	0,8	1,9	3,1	2,6	2,1	1,5	1,5
08. Passenger rail transport		0,3	0,4	0,5	0,3	0,4	0,4	0,4
10. Ind.&comm. refriger.	6,2	58,1	117,2	173,0	198,6	198,0	195,3	195,9
11. Closed cell foam		0,0	0,9	1,8	2,5	2,6	2,7	2,8
12. PU cans	31,4	21,5	3,1	0,3	0,4	2,3	2,7	0,3
13. Aerosols MDI		0,0	3,8	4,7	5,1	5,2	5,0	5,0
14. Other aerosols	3,9	4,3	4,1	2,7	4,0	4,3	3,4	3,4
17. SF6 electr. Sector	0,5	0,6	0,8	1,5	1,0	1,1	1,7	1,2
18. SF6 in glass sector	1,0	1,4	5,0	8,7	8,3	8,2	8,0	7,9
19. Fire Extinguishers	0,1	0,5	1,2	1,4	1,4	1,3	1,3	1,3
22. Nike shoes	4,4	4,4	0,8					
Total	50,2	105,9	172,9	261,0	310,0	311,4	308,9	303,9

Figure 41 and Table 28 present the emissions of the CRF-gases by CRF source category, in terms of CO₂ equivalents. The largest emission source here is 'Commercial refrigeration', which includes industrial refrigeration. Striking is the large and increasing share of Fluorochemical production.

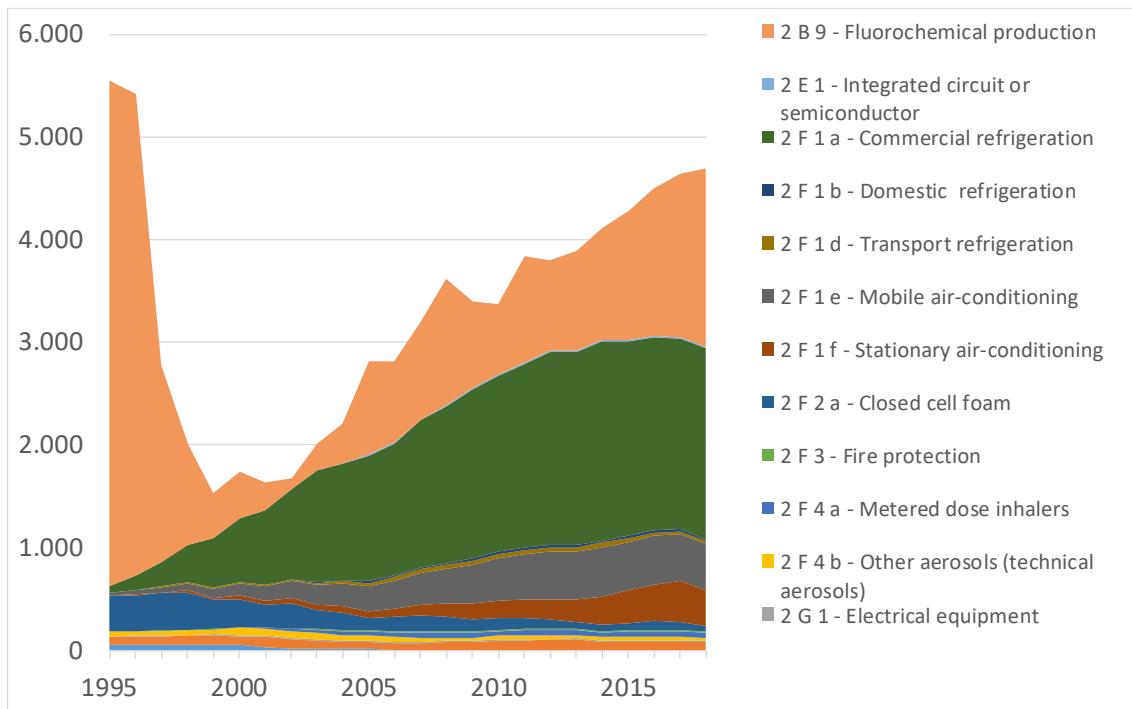
**Figure 41: Evolution of CRF-gas emissions by source (kt CO2 eq)**

Table 28: Evolution of the CRF-gas emissions by CRF source, in kt CO₂-eq

(kt CO ₂ -eq)	CRF Name	1995	2000	2005	2010	2016	2017	2018
2 B 9	Fluorochemical production	4.919,6	445,9	900,2	684,1	1.440,7	1.590,8	1.740,0
2 E 1	Integrated circuit or semiconductor			17,8	13,0	21,1	19,0	20,7
2 F 1 a	Commercial refrigeration	65,7	619,9	1.216,5	1.721,5	1.877,9	1.855,2	1.859,4
2 F 1 b	Domestic refrigeration	0,1	2,6	23,1	18,7	21,4	20,4	19,1
2 F 1 d	Transport refrigeration	1,5	10,6	26,6	41,3	30,0	21,0	21,5
2 F 1 e	Mobile air-conditioning	23,5	117,6	245,8	412,7	471,5	460,6	451,9
2 F 1 f	Stationary air-conditioning	1,8	45,9	67,8	165,5	351,2	393,3	350,5
2 F 2 a	Closed cell foam	356,8	268,1	122,2	119,5	92,1	87,1	54,1
2 F 3	Fire protection	0,6	4,9	12,4	14,0	12,5	12,6	12,0
2 F 4 a	Metered dose inhalers			0,4	39,7	46,5	49,0	47,2
2 F 4 b	Other aerosols (technical aerosols)	41,5	70,3	50,3	34,6	45,1	35,7	32,7
2 G 1	Electrical equipment	8,0	9,6	11,2	15,8	11,7	19,4	13,1
2 G 2 c	Soundproof windows	79,8	87,8	69,9	86,2	77,4	76,0	74,5
2 G 2 d	Adiabatic properties: shoes and tyres	46,9	47,0	8,0				
Total		5.545,7	1.730,5	2.811,4	3.373,4	4.501,8	4.638,2	4.696,9

(*) This category also includes industrial refrigeration.

The ODS gas emissions, which fall under the Montreal protocol and are expressed in tonnes CFC11-eq, have strongly declined, the main remaining share being that of closed cell foams (CFC11 in polyurethane foams and CFC12 in polystyrene foams).

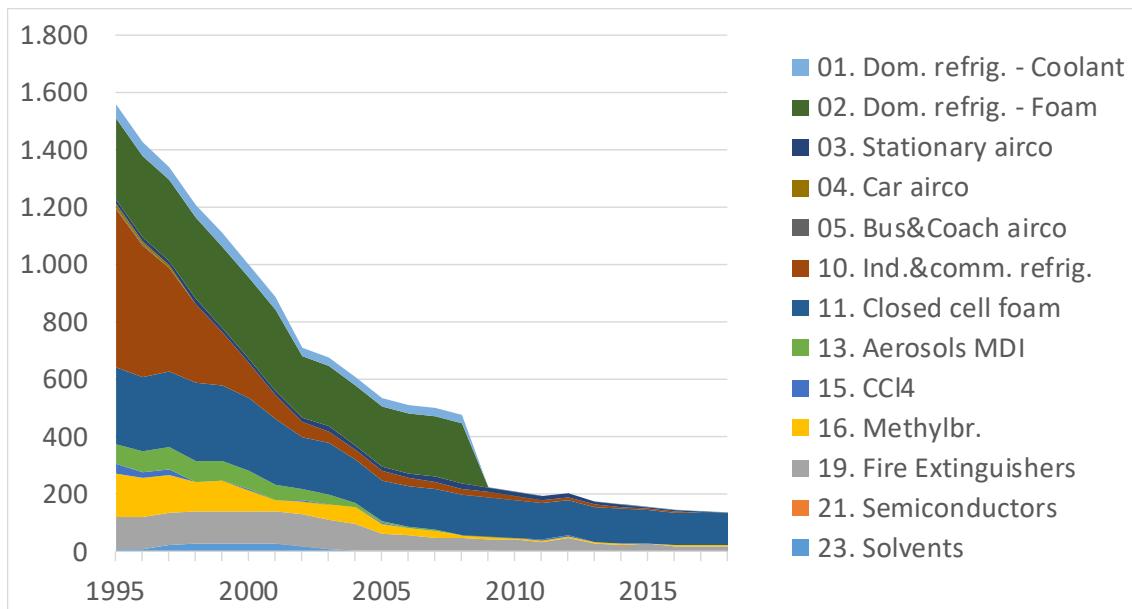
**Figure 42: Evolution of ODS gas emissions by source (t CFC11-eq)**

Table 29: Evolution of the emissions of ODS gases by source, in t CFC11-eq

(t CFC-11 eq)	1995	2000	2005	2010	2014	2016	2017	2018
01. Dom. refriger. - Coolant	47,30	44,98	29,96					
02. Dom. refriger. - Foam	286,07	282,04	210,65	0,00				
03. Stationary airco	14,03	17,68	15,23	13,60	8,28	4,63	3,06	0,95
04. Car airco	13,91							
05. Bus&Coach airco	6,29							
10. Ind.&comm. refriger.	547,93	123,55	30,83	16,67	4,74	2,11	0,81	0,46
11. Closed cell foam	268,51	250,53	145,27	130,51	120,83	116,36	114,21	112,11
13. Aerosols MDI	69,39	66,20	4,94	0,06				
15. CCl4	32,10	0,74	0,74	0,74	0,74			
16. Methylbr.	154,76	76,99	34,38	6,36	4,48	1,29	1,72	2,20
19. Fire Extinguishers	112,95	112,95	61,41	40,57	23,39	18,92	18,49	18,95
21. Semiconductors	0,00			0,00				
23. Solvents	5,50	24,75	1,65					
Total	1.558,74	1.000,42	535,07	208,51	162,47	143,31	138,29	134,67

8 UNCERTAINTY ANALYSIS

8.1 Methodology

8.1.1 Introduction

The methodology used for the uncertainty analysis has been described in detail in the update for 2004 [28]. 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* [29], which itself relies on the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* [30].

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 [2], for the years 1995, 2012 and 2013.

As stated in [29]¹⁶, the greenhouse gas inventory is principally the sum of products of activity data and emission factors. In a simplified way¹⁷:

$$E_T = \sum E_i = \sum AV_i \cdot EF_i,$$

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.

¹⁶ Page 6.12.

¹⁷ 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.

8.1.2 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, 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.

8.1.3 Combination of uncertainties

8.1.3.1 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 ($CV = \sigma/m$):

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

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

$$E = AV \cdot EF,$$

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

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

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 [29].

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:

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

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. [31], p. 227):

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

Since $CV = \sigma/m$ and $U = 1,96 \sigma/m$, one has indeed: $CV = U/1,96$.

8.1.3.2 Sum of stochastic variables

If the total emission of a gas is :

$$E = \sum E_i,$$

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 :

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

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

This equation is equation 3.2 of [2], volume 1, p. 3.28.

8.1.3.3 Approaches 1 and 2 of the IPCC

The 2006 IPCC Guidelines provide two approaches¹⁸ 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 can not 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.

¹⁸ These approaches used to be called Tier 1 and Tier 2 in the 1996 IPCC Guidelines.

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.
- According to the central limit theorem¹⁹, 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” ([2], 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).

8.1.4 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).

¹⁹ 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).

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.

8.1.5 Trend uncertainties

As required by the IPCC, trend uncertainties are estimated using two sensitivities ([2], 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.

8.2 Results of the uncertainty analysis

8.2.1 Introduction

As requested, the uncertainty evaluation has been updated for the years 1995, 2015 and 2016. 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 [29], which is to be used for the official reporting.

As the results of the emission inventory show, the size of emission level can differ very widely from one source to another. Therefore, we have limited the uncertainty analysis to the largest individual sources, which together account for 99% of the Kyoto F-gas emissions in 1995 and 95% of emissions in 2005, and used extrapolation to cover the remaining emissions (identified as “other” categories).

After some comments on the data sources, this section analyses the assumptions by emission source and by substance. 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 [28].

8.2.2 Result tables

The results are presented in the tables hereafter, which have the format of Table 6.1 of the IPCC Guidelines and relate to the years 1995 (update), 2015 (update) and 2016.

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.

One difficulty in getting accurate emission figures stems from the fact that the F-gases are all imported, and that there are no statistics on external trade of these substances. This is particularly the case for a small country like Belgium which is characterised by a high level of external trade.

Overall, the results show for the F-gases an uncertainty of 1,0% of the total greenhouse gas emissions in 2016. The trend uncertainty is estimated at 0,9%.

Table 3.2: Approach 1 uncertainty calculation and reporting for year 1995 - page 1

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC Source category	Gas	Base year emissions (F-gases : 1995 otherwise : 1990)	1995 emissions	Activity data uncertainty (%)	Emission factor uncertainty (%)	Combined uncertainty	Contribution to Variance by Category in 1995	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	$\sqrt{E^2 + F^2 + \frac{1}{38} E^2 F^2}$	$\frac{(G * D)^2}{(\sum D)^2}$	Note B	$\frac{D}{\sum C}$	$I * F$	$J * E * \sqrt{2}$	$\sqrt{K^2 + L^2}$
2 B 9 a By-product emissions	CF4	511,68	511,68	26%	0%	26%	0,0001%					
2 B 9 a By-product emissions	C2F6	875,85	875,85	26%	0%	26%	0,0002%					
2 B 9 a By-product emissions	C3F8	294,50	294,50	26%	0%	26%	0,0000%					
2 B 9 a By-product emissions	C4F10	333,52	333,52	26%	0%	26%	0,0000%					
2 B 9 a By-product emissions	CSF12	58,04	58,04	26%	0%	26%	0,0000%					
2 B 9 a By-product emissions	SF6	2.005,28	2.005,28	26%	0%	26%	0,013%					
2 B 9 b Fugitive emissions	C4F10	37,06	37,06	26%	0%	26%	0,0000%					
2 B 9 b Fugitive emissions	CSF12	497,50	497,50	26%	0%	26%	0,0001%					
2 B 9 b Fugitive emissions	C6F14	306,15	306,15	26%	0%	26%	0,0000%					
2 E 1 Semiconductors	HFC-23	0,00	0,00		100%	100%	0,0000%					
2 E 1 Semiconductors	CF4	0,00	0,00		100%	100%	0,0000%					
2 E 1 Semiconductors	C2F6	0,00	0,00		100%	100%	0,0000%	NOT RELEVANT FOR BASE YEAR				
2 E 1 Semiconductors	c-C4F8	0,00	0,00		100%	100%	0,0000%					
2 E 1 Semiconductors	SF6	0,00	0,00		100%	100%	0,0000%					
2 E 1 Semiconductors	NF3	0,00	0,00		100%	100%	0,0000%					
2 E 4 Heat transfer fluid	HFC-32	0,00	0,00		100%	100%	0,0000%					
2 E 4 Heat transfer fluid	HFC-125	0,00	0,00		100%	100%	0,0000%					
2 F 1 a Commercial refrigeration	HFC-125	4,26	4,26		75%	75%	0,0000%					
2 F 1 a Commercial refrigeration	HFC-134a	55,02	55,02		75%	75%	0,0000%					
2 F 1 a Commercial refrigeration	HFC-143a	6,38	6,38		75%	75%	0,0000%					
2 F 1 a Commercial refrigeration	HFC-152a	0,00	0,00		75%	75%	0,0000%					
2 F 1 a Commercial refrigeration	C3F8 (PFC-218)	0,00	0,00		75%	75%	0,0000%					
2 F 1 a Commercial refrigeration	C3F8 (PFC-218)	0,00	0,00		75%	75%	0,0000%					
2 F 1 b Domestic refrigeration	HFC-134a	0,05	0,05		75%	75%	0,0000%					
2 F 1 d Transport refrigeration	HFC-32	0,00	0,00	100%	50%	115%	0,0000%					
2 F 1 d Transport refrigeration	HFC-125	0,57	0,57	100%	50%	115%	0,0000%					
2 F 1 d Transport refrigeration	HFC-134a	0,12	0,12	100%	50%	115%	0,0000%					
2 F 1 d Transport refrigeration	HFC-143a	0,86	0,86	100%	50%	115%	0,0000%					

Table 3.2 : Approach 1 uncertainty calculation and reporting for the year 1995 - page 2

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC Source category	Gas	Base year emissions (F-gases : 1995 otherwise : 1990)	1995 emissions	Activity data uncertainty (%)	Emission factor uncertainty (%)	Combined uncertainty	Contribution to Variance by Category in 1995	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	$\sqrt{E^2 + F^2 + \frac{1}{38} E^2 F^2}$	$\frac{(G * D)^2}{(\sum D)^2}$	Note B	$\frac{D}{\sum C}$	$I * F$	$J * E * \sqrt{2}$	$\sqrt{K^2 + L^2}$
2 F 1 e Mobile air-conditioning	HFC-134a	23,51	23,51	100%	50%	115%	0,0000%					
2 F 1 f Stationary air-conditioning	HFC-32	0,09	0,09	100%	50%	115%	0,0000%					
2 F 1 f Stationary air-conditioning	HFC-125	0,50	0,50	100%	50%	115%	0,0000%					
2 F 1 f Stationary air-conditioning	HFC-134a	1,21	1,21	15%	5%	16%	0,0000%					
2 F 2 a Closed cell foam	HFC-134a	356,73	356,73	15%	5%	16%	0,0000%					
2 F 2 a Closed cell foam	HFC-152a	0,06	0,06	15%	5%	16%	0,0000%					
2 F 2 a Closed cell foam	HFC-227ea	0,00	0,00	15%	5%	16%	0,0000%					
2 F 2 a Closed cell foam	HFC-245fa	0,01	0,01	15%	5%	16%	0,0000%					
2 F 2 a Closed cell foam	HFC-365mfc	0,00	0,00	10%	50%	51%	0,0000%	NOT RELEVANT FOR BASE YEAR				
2 F 3 Fire protection	HFC-125	0,00	0,00	10%	50%	51%	0,0000%					
2 F 3 Fire protection	HFC-227ea	0,58	0,58	25%	50%	56%	0,0000%					
2 F 4 a Metered dose inhalers	HFC-134a	0,00	0,00	25%	50%	56%	0,0000%					
2 F 4 a Metered dose inhalers	HFC-227ea	0,00	0,00		200%	200%	0,0000%					
2 F 4 b Technical aerosols	HFC-134a	41,41	41,41		200%	200%	0,0000%					
2 F 4 b Technical aerosols	HFC-152a	0,04	0,04		50%	50%	0,0000%					
2 G 1 Electrical equipment	SF6	8,01	8,01		100%	100%	0,0000%					
2 G 2 c Soundproof windows	SF6	79,77	79,77		100%	100%	0,0000%					
2 G 2 d Adiabatic properties: shoes	SF6	46,93	46,93		100%	100%	0,0000%					
Total F-gases		5.545,70	5.545,70				0,0019%					
Total 6 GHG (without LUCF)		146.654,02	146.294,18			Percentage uncertainty in total inventory	0,432%					

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.

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

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 2017 - page 1

A IPCC Source category	B Gas	C Base year emissions (F- gases : 1995 otherwise : 1990)	D 2017 emissions	E Activity data uncertainty (%)	F Emission factor uncertainty (%)	G Combined uncertainty	H Contribution to Variance by Category in 2017	I Type A sensitivity	J Type B sensitivity	K Uncertainty in trend in national emissions introduced by emission factor uncertainty	L Uncertainty in trend in national emissions introduced by activity data uncertainty	M Uncertainty introduced into the trend in total national emissions
		Gg CO ₂ eq	Gg CO ₂ 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 $	$J * E * \sqrt{2}$	$\sqrt{K^2 + L^2}$
2B 9 a By-product emissions	HFCs	511,68	98,55	26%	0%	26%	0,0000%	-0,002%	0,001%	0,00%	0,02%	0,025%
2B 9 a By-product emissions	C2F6 (PFC-116)	875,85	0,00	26%	0%	26%	0,0000%	-0,005%	0,000%	0,00%	0,00%	0,000%
2B 9 a By-product emissions	C3F8 (PFC-218)	294,50	0,00	26%	0%	26%	0,0000%	-0,002%	0,000%	0,00%	0,00%	0,000%
2B 9 a By-product emissions	C4F10	333,52	0,00	26%	0%	26%	0,0000%	-0,002%	0,000%	0,00%	0,00%	0,000%
2B 9 a By-product emissions	C5F12	58,04	0,00	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2B 9 a By-product emissions	SF6	2.005,28	0,00	26%	0%	26%	0,0000%	-0,011%	0,000%	0,00%	0,00%	0,000%
2B 9 b Fugitive emissions	HFC-23	0,00	1.269,97	26%	0%	26%	0,0008%	0,009%	0,009%	0,00%	0,32%	0,318%
2B 9 b Fugitive emissions	HFC-125	0,00	114,78	26%	0%	26%	0,0000%	0,001%	0,001%	0,00%	0,03%	0,029%
2B 9 b Fugitive emissions	HFC-134a	0,00	0,80	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2B 9 b Fugitive emissions	HFC-227ea	0,00	36,87	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,01%
2B 9 b Fugitive emissions	C4F10	37,06	64,05	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,016%
2B 9 b Fugitive emissions	C5F12	497,50	0,00	26%	0%	26%	0,0000%	-0,003%	0,000%	0,00%	0,00%	0,000%
2B 9 b Fugitive emissions	C6F14	306,15	5,74	26%	0%	26%	0,0000%	-0,002%	0,000%	0,00%	0,00%	0,001%
2E 1 Semiconductors	HFCs	0,00	1,27		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2E 1 Semiconductors	HFCs	0,00	0,01		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2E 1 Semiconductors	HFCs	0,00	0,00		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2E 1 Semiconductors	HFCs	0,00	0,04		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2E 1 Semiconductors	CF4	0,00	4,53		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,003%
2E 1 Semiconductors	C2F6 (PFC-116)	0,00	6,16		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,004%
2E 1 Semiconductors	c-C4F8	0,00	0,14		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2E 1 Semiconductors	SF6	0,00	6,19		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,004%
2E 1 Semiconductors	NF3	0,00	0,63		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2F 1 a Commercial refrigeration	HFC-32	0,00	10,77		75%	75%	0,0000%	0,000%	0,000%	0,01%	0,00%	0,006%
2F 1 a Commercial refrigeration	HFC-125	4,26	666,26		75%	75%	0,0019%	0,005%	0,005%	0,34%	0,00%	0,339%
2F 1 a Commercial refrigeration	HFC-134a	55,02	395,04		75%	75%	0,0007%	0,002%	0,003%	0,18%	0,00%	0,180%
2F 1 a Commercial refrigeration	HFC-143a	6,38	783,15		75%	75%	0,0026%	0,005%	0,005%	0,40%	0,00%	0,398%
2F 1 a Commercial refrigeration	HFC-152a	0,00	0,00		75%	75%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2F 1 a Commercial refrigeration	C3F8 (PFC-218)	0,00	0,01		75%	75%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2F 1 b Domestic refrigeration	HFC-125	0,00	4,88		75%	75%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,002%
2F 1 b Domestic refrigeration	HFC-134a	0,05	8,17		75%	75%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,004%
2F 1 b Domestic refrigeration	HFC-143a	0,00	7,37		75%	75%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,004%

Table 3.2 : Approach 1 uncertainty calculation and reporting for the year 2017 - page 2

A IPCC Source category	B Gas	C Base year emissions (F-gases : 1995 otherwise : 1990)	D 2017 emissions	E Activity data uncertainty (%)	F Emission factor uncertainty (%)	G Combined uncertainty	H Contribution to Variance by Category in 2017	I Type A sensitivity	J Type B sensitivity	K Uncertainty in trend in national emissions introduced by emission factor uncertainty	L Uncertainty in trend in national emissions introduced by activity data uncertainty	M Uncertainty introduced into the trend in total national emissions
		Gg CO2 eq	Gg CO2 eq									
		Input data	Input data	Input data	Input data	$\sqrt{E^2 + F^2 + \frac{1}{38} E^2 F^2}$	$\frac{(G * D)^2}{(\sum D)^2}$	Note B	$\frac{D}{\sum C}$	$ I * F $	$J * E * \sqrt{2}$	$\sqrt{K^2 + L^2}$
2 F 1 d Transport refrigeration	HFC-32	0,00	0,22	100%	50%	115%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 F 1 d Transport refrigeration	HFC-125	0,57	8,12	100%	50%	115%	0,0000%	0,000%	0,000%	0,00%	0,01%	0,008%
2 F 1 d Transport refrigeration	HFC-134a	0,12	2,14	100%	50%	115%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,002%
2 F 1 d Transport refrigeration	HFC-143a	0,86	10,51	100%	50%	115%	0,0000%	0,000%	0,000%	0,00%	0,01%	0,011%
2 F 1 e Mobile air-conditioning	HFC-32	0,00	0,07	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	0,38	100%	50%	115%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 F 1 e Mobile air-conditioning	HFC-134a	23,51	460,19	100%	50%	115%	0,0021%	0,003%	0,003%	0,15%	0,44%	0,469%
2 F 1 f Stationary air-conditioning	HFC-32	0,09	34,49		75%	75%	0,0000%	0,000%	0,000%	0,02%	0,00%	0,018%
2 F 1 f Stationary air-conditioning	HFC-125	0,50	186,78		75%	75%	0,0001%	0,001%	0,001%	0,10%	0,00%	0,095%
2 F 1 f Stationary air-conditioning	HFC-134a	1,21	172,03		75%	75%	0,0001%	0,001%	0,001%	0,09%	0,00%	0,087%
2 F 1 f Stationary air-conditioning	HFC-143a	0,00	0,04		75%	75%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 F 2 a Closed cell foam	HFC-134a	356,73	57,72	15%	5%	16%	0,0000%	-0,002%	0,000%	-0,01%	0,01%	0,011%
2 F 2 a Closed cell foam	HFC-152a	0,06	12,34	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	5,57	15%	5%	16%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2 F 2 a Closed cell foam	HFC-245fa	0,01	0,53	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	10,91	15%	5%	16%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,002%
2 F 3 Fire protection	HFC-125	0,00	0,86	10%	50%	51%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 F 3 Fire protection	HFC-227ea	0,58	11,71	10%	50%	51%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,004%
2 F 4 a Metered dose inhalers	HFC-134a	0,00	45,52	25%	50%	56%	0,0000%	0,000%	0,000%	0,02%	0,01%	0,019%
2 F 4 a Metered dose inhalers	HFC-227ea	0,00	1,67	25%	50%	56%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2 F 4 b Technical aerosols	HFC-134a	41,41	35,62		200%	200%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,004%
2 F 4 b Technical aerosols	HFC-152a	0,04	0,08		200%	200%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 G 1 Electrical equipment	SF6	8,01	19,36		50%	50%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,004%
2 G 2 c Soundproof windows	SF6	79,77	75,98		100%	100%	0,0000%	0,000%	0,001%	0,01%	0,00%	0,009%
2 G 2 d Adiabatic properties: shoes	SF6	46,93	0,00		100%	100%	0,0000%	0,000%	0,000%	-0,02%	0,00%	0,025%
Total F-gases		5.545,70	4.638,20				0,0085%					0,006%
Total 7 GHGs (without LUCF)		146.654,02	114.539,90			Percentage uncertainty in total inventory	0,924%			Trend uncertainty		0,804%

Notes: see under calculation for base year (1995)

Table 3.2: Approach 1 uncertainty calculation and reporting for year 2018 - page 1

A IPCC Source category	B Gas	C Base year emissions (F- gases : 1995 otherwise : 1990)	D 2018 emissions	E Activity data uncertainty (%)	F Emission factor uncertainty (%)	G Combined uncertainty	H Contribution to Variance by Category in 2018	I Type A sensitivity	J Type B sensitivity	K Uncertainty in trend in national emissions introduced by emission factor uncertainty	L Uncertainty in trend in national emissions introduced by activity data uncertainty	M 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	HFCs	511,68	89,56	26%	0%	26%	0,0000%	-0,002%	0,001%	0,00%	0,02%	0,022%
2 B 9 a By-product emissions	C2F6 (PFC-116)	875,85	0,00	26%	0%	26%	0,0000%	-0,005%	0,000%	0,00%	0,00%	0,000%
2 B 9 a By-product emissions	C3F8 (PFC-218)	294,50	0,00	26%	0%	26%	0,0000%	-0,002%	0,000%	0,00%	0,00%	0,000%
2 B 9 a By-product emissions	C4F10	333,52	0,00	26%	0%	26%	0,0000%	-0,002%	0,000%	0,00%	0,00%	0,000%
2 B 9 a By-product emissions	CSF12	58,04	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	2.005,28	0,00	26%	0%	26%	0,0000%	-0,011%	0,000%	0,00%	0,00%	0,000%
2 B 9 b Fugitive emissions	HFC-23	0,00	1.506,24	26%	0%	26%	0,0012%	0,010%	0,010%	0,00%	0,38%	0,378%
2 B 9 b Fugitive emissions	HFC-125	0,00	102,19	26%	0%	26%	0,0000%	0,001%	0,001%	0,00%	0,03%	0,026%
2 B 9 b Fugitive emissions	HFC-134a	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-227ea	0,00	11,10	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,003%
2 B 9 b Fugitive emissions	C4F10	37,06	25,22	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,01%	0,006%
2 B 9 b Fugitive emissions	CSF12	497,50	0,00	26%	0%	26%	0,0000%	-0,003%	0,000%	0,00%	0,00%	0,000%
2 B 9 b Fugitive emissions	C6F14	306,15	5,64	26%	0%	26%	0,0000%	-0,002%	0,000%	0,00%	0,00%	0,001%
2 E 1 Semiconductors	HFC-23	0,00	1,59		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2 E 1 Semiconductors	HFC-32	0,00	0,02		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	HFC-125	0,00	0,12		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 E 1 Semiconductors	CF4	0,00	5,01		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,003%
2 E 1 Semiconductors	C2F6 (PFC-116)	0,00	5,78		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,004%
2 E 1 Semiconductors	c-C4F8	0,00	0,10		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 E 1 Semiconductors	SF6	0,00	7,40		100%	100%	0,0000%	0,000%	0,000%	0,01%	0,00%	0,005%
2 E 1 Semiconductors	NF3	0,00	0,65		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 F 1 a Commercial refrigeration	HFC-32	0,00	12,74		75%	75%	0,0000%	0,000%	0,000%	0,01%	0,00%	0,007%
2 F 1 a Commercial refrigeration	HFC-125	4,26	686,68		75%	75%	0,0020%	0,005%	0,005%	0,35%	0,00%	0,349%
2 F 1 a Commercial refrigeration	HFC-134a	55,02	366,68		75%	75%	0,0006%	0,002%	0,003%	0,17%	0,00%	0,166%
2 F 1 a Commercial refrigeration	HFC-143a	6,38	793,24		75%	75%	0,0027%	0,005%	0,005%	0,40%	0,00%	0,403%
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 (PFC-218)	0,00	0,01		75%	75%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 F 1 b Domestic refrigeration	HFC-125	0,00	4,62		75%	75%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,002%
2 F 1 b Domestic refrigeration	HFC-134a	0,05	7,52		75%	75%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,004%
2 F 1 b Domestic refrigeration	HFC-143a	0,00	6,97		75%	75%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,004%

Table 3.2 : Approach 1 uncertainty calculation and reporting for the year 2018 - page 2

A IPCC Source category	B Gas	C Base year emissions (F- gases : 1995 otherwise : 1990)	D 2018 emissions	E Activity data uncertainty (%)	F Emission factor uncertainty (%)	G Combined uncertainty	H Contribution to Variance by Category in 2018	I Type A sensitivity	J Type B sensitivity	K Uncertainty in trend in national emissions introduced by emission factor uncertainty	L Uncertainty in trend in national emissions introduced by activity data uncertainty	M Uncertainty introduced into the trend in total national emissions
		Gg CO2 eq	Gg CO2 eq									
		Input data	Input data	Input data	Input data	$\sqrt{E^2 + F^2 + \frac{1}{38} E^2 F^2}$	$\frac{(G * D)^2}{(\sum D)^2}$	Note B	$\frac{D}{\sum C}$	$ I * F $	$J * E * \sqrt{2}$	$\sqrt{K^2 + L^2}$
2 F 1 d Transport refrigeration	HFC-32	0,00	0,24	100%	50%	115%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 F 1 d Transport refrigeration	HFC-125	0,57	8,46	100%	50%	115%	0,0000%	0,000%	0,000%	0,00%	0,01%	0,009%
2 F 1 d Transport refrigeration	HFC-134a	0,12	2,18	100%	50%	115%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,002%
2 F 1 d Transport refrigeration	HFC-143a	0,86	10,63	100%	50%	115%	0,0000%	0,000%	0,000%	0,00%	0,01%	0,011%
2 F 1 e Mobile air-conditioning	HFC-32	0,00	0,13	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	0,74	100%	50%	115%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2 F 1 e Mobile air-conditioning	HFC-134a	23,51	451,04	100%	50%	115%	0,0020%	0,003%	0,003%	0,15%	0,43%	0,459%
2 F 1 f Stationary air-conditioning	HFC-32	0,09	34,32		75%	75%	0,0000%	0,000%	0,000%	0,02%	0,00%	0,018%
2 F 1 f Stationary air-conditioning	HFC-125	0,50	183,71		75%	75%	0,0001%	0,001%	0,001%	0,09%	0,00%	0,094%
2 F 1 f Stationary air-conditioning	HFC-134a	1,21	132,42		75%	75%	0,0001%	0,001%	0,001%	0,07%	0,00%	0,067%
2 F 1 f Stationary air-conditioning	HFC-143a	0,00	0,02		75%	75%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 F 2 a Closed cell foam	HFC-134a	356,73	26,17	15%	5%	16%	0,0000%	-0,002%	0,000%	-0,01%	0,00%	0,009%
2 F 2 a Closed cell foam	HFC-152a	0,06	16,01	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	4,18	15%	5%	16%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2 F 2 a Closed cell foam	HFC-245fa	0,01	0,53	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	7,20	15%	5%	16%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2 F 3 Fire protection	HFC-125	0,00	0,81	10%	50%	51%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 F 3 Fire protection	HFC-227ea	0,58	11,23	10%	50%	51%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,004%
2 F 4 a Metered dose inhalers	HFC-134a	0,00	45,73	25%	50%	56%	0,0000%	0,000%	0,000%	0,02%	0,01%	0,019%
2 F 4 a Metered dose inhalers	HFC-227ea	0,00	1,68	25%	50%	56%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2 F 4 b Technical aerosols	HFC-134a	41,41	32,59		200%	200%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 F 4 b Technical aerosols	HFC-152a	0,04	0,09		200%	200%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 G 1 Electrical equipment	SF6	8,01	13,13		50%	50%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,002%
2 G 2 c Soundproof windows	SF6	79,77	74,55		100%	100%	0,0000%	0,000%	0,001%	0,01%	0,00%	0,008%
2 G 2 d Adiabatic properties: shoes	SF6	46,93	0,00		100%	100%	0,0000%	0,000%	0,000%	-0,02%	0,00%	0,025%
Total F-gases		5.545,70	4.696,88				0,0088%					0,007%
Total 7 GHGs (without LUCF)		146.654,02	114.539,90 (2017)			Percentage uncertainty in total inventory	0,939%				Trend uncertainty	0,826%

Notes: see under calculation for base year (1995)

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10 ABBREVIATIONS

AR4	Fourth Assessment Report of the IPCC
CFC	Chlorofluorocarbon
CRF	Common Reporting Format of the UNFCCC
CRF-gases	the compulsory gases of the UNFCCC reporting
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
HFE	Hydrofluoroether
HFO	Hydrofluoroolefin
IPCC	Intergovernmental Panel on Climate Change
Kyoto-gases	see CRF-gases
MDI	Metered Dose Inhaler
NF3	Nitrogen trifluoride
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

11 ANNEXES

Annex 1 : Global Warming Potential (GWP) and Ozone Depleting Potential (ODP)

Note : for ozone depleting substances, the GWP values used are, as far as the relevant data are available, net GWPs, taking into account the indirect greenhouse effect of these substances, evaluated as the average of two extreme values.

Table 30: GWP_s and ODP_s

Substance	Group of substances	ODS/CRF	GWP 100 years (CO ₂ =1)	Source GWP values	ODP (CFC11=1)
CFC-11	CFC	ODS	2.020	AR5	1
CFC-12	CFC	ODS	8.100	AR5	1
CFC-114	CFC	ODS	7.676	AR5	1
CFC-115	CFC	ODS	7.447	AR5	0,6
Halon 1211	Halons	ODS	-17.250	AR5	3
Halon 1301	Halons	ODS	-38.210	AR5	10
HCFC-22	HCFC	ODS	1.662	AR5	0
HCFC-124	HCFC	ODS	481	AR5	0,022
HCFC-141b	HCFC	ODS	521	AR5	0,11
HCFC-142b	HCFC	ODS	1.828	AR5	0,065
CCI4	Other ODS	ODS	-380	AR5	1,1
CH3Br	Other ODS	ODS	-1.248	AR5	0,6
HFC-23	HFC	CRF	14.800	AR4	0
HFC-32	HFC	CRF	675	AR4	0
HFC-41	HFC	CRF	92	AR4	0
HFC-43-10mee	HFC	CRF	1.640	AR4	0
HFC-125	HFC	CRF	3.500	AR4	0
HFC-134	HFC	CRF	1.100	AR4	0
HFC-134a	HFC	CRF	1.430	AR4	0
HFC-143	HFC	CRF	353	AR4	0
HFC-143a	HFC	CRF	4.470	AR4	0
HFC-152	HFC	CRF	53	AR4	0
HFC-152a	HFC	CRF	124	AR4	0
HFC-161	HFC	CRF	12	AR4	0
HFC-227ea	HFC	CRF	3.220	AR4	0
HFC-236cb	HFC	CRF	1.340	AR4	0
HFC-236ea	HFC	CRF	1.370	AR4	0
HFC-236fa	HFC	CRF	9.810	AR4	0
HFC-245ca	HFC	CRF	693	AR4	0
HFC-245fa	HFC	CRF	1.030	AR4	0
HFC-365mfc	HFC	CRF	794	AR4	0
CF4	PFC	CRF	7.390	AR4	0
C2F6 (PFC-116)	PFC	CRF	12.200	AR4	0
C3F8 (PFC-218)	PFC	CRF	8.830	AR4	0
C4F10	PFC	CRF	8.860	AR4	0
c-C4F8	PFC	CRF	10.300	AR4	0
C5F12	PFC	CRF	9.160	AR4	0
C6F14	PFC	CRF	9.300	AR4	0
C10F18 (PFC-9-1-18)	PFC	CRF	7.500	AR4	0
c-C3F6 (PFC-216)	PFC	CRF	17.340	AR4	0
SF6	SF6	CRF	22.800	AR4	0
NF3	NF3	CRF	17.200	AR4	0
CF3SF5	Other	Other	17.400	AR5	0
C7F16	PFC	Other	7.700	3M	0
C8F18	PFC	Other	8.000	3M	0
C8F16O	Other	Other	9.400	3M	0
PFPMIE	Other	Other	9.710	AR5	0
R-1233zd	HCFO	Other	7	AR5	0
R-1234yf	HFO	Other	4	AR5	0
R-1234ze	HFO	Other	6	AR5	0

AR4: Fourth Assessment Report of the IPCC [3]

AR5: Fifth Assessment Report of the IPCC [4]

Annex 2: List of emission sources

Table 31: List of emission sources with their allocation to the CRF source categories

Name of Worksheet	NFR Code	CRF source category
01. Dom. refriger. - Coolant	2 F 1 b	Domestic refrigeration
02. Dom. refriger. - Foam	2 F 2 a	Closed cell foam
03. Stationary airco	2 F 1 f	Stationary air-conditioning
04. Car airco	2 F 1 e	Mobile air-conditioning
05. Bus&Coach airco	2 F 1 e	Mobile air-conditioning
06. Trucks airco	2 F 1 e	Mobile air-conditioning
07. Refrigerated transport	2 F 1 d	Transport refrigeration
08. Passenger rail transport	2 F 1 e	Mobile air-conditioning
10. Ind.&comm. refriger.	2 F 1 a	Commercial refrigeration
11. Closed cell foam	2 F 2 a	Closed cell foam
12. PU cans	2 F 2 a	Closed cell foam
13. Aerosols MDI	2 F 4 a	Metered dose inhalers
14. Other aerosols	2 F 4 b	Other aerosols (technical aerosols)
15. CCl4	XXX	CCl4
16. Methylbr.	YYY	Methyl bromide
17. SF6 electr. Sector	2 G 1	Electrical equipment
18. SF6 in glass sector	2 G 2 c	Soundproof windows
19. Fire Extinguishers	2 F 3	Fire protection
20. Chemical Ind	2 B 9	Fluorochemical production
21. Semiconductors	2 E 1	Integrated circuit or semiconductor
22. Nike shoes	2 G 2 d	Adiabatic properties: shoes and tyres
23. Solvents	ZZZ	Solvents

Annex 3: Common Reporting Format (CRF) nomenclature

Table 32: Nomenclature of the CRF format

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

Annex 4: Refrigerant mix composition

ASHRAE Number	GWP	R22	R124	R142b	R32	R23	R125	R134a	R143a	R152a	R227ea	R116	R218	R1234yf	R290	R600	R600a	R601	R601a	R744 CO2
AR4	HCFC	HCFC	HCFC	HFC	HFC	HFC	HFC	HFC	HFC	HFC	PFC	PFC	PFC	HFO	Propane	Butane	Isobutane	Pentane	Isopentane	
R401A	1061	53,0%	34,0%																	
R402A	2732	38,0%						60,0%											2,0%	
R403B	4374	56,0%																	5,0%	
R404A	3922																			
R407A	2107																			
R407C	1774																			
R407F	1825																			
R407H	1495																			
R408A	3082	47,0%																		
R409A	1392	60,0%	25,0%	15,0%																
R410A	2088							50,0%												
R413A	2053																			
R417A	2346																			
R421B	3190																			
R422A	3143																			
R422D	2729																			
R423A	2280																			
R424A	2440																			
R426A	1508																			
R427A	2138																			
R428A	3607																			
R434A	3245																			
R437A	1805																			
R438A	2264																			
R442A	1888																			
R448A	1387																			
R449A	1397																			
R450A	604																			
R452A	2140																			
R452B	698																			
R454A	239																			
R454B	466																			
R454C	148																			
R455A	148																			
R507A	3985																			
R508A	13214																			
R508B	13396																			
R513A	631																			
R513B	596																			
R515A	390																			