

UPDATE OF THE NATIONAL EMISSION INVENTORY OF OZONE DEPLETING SUBSTANCES AND FLUORINATED GREENHOUSE GASES (1995-2016)

Final report

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Contents

LIST OF TABLES	5
LIST OF FIGURES.....	6
1 EXECUTIVE SUMMARY.....	7
2 INTRODUCTION	9
3 WORK PROGRAMME	9
3.1 GASES CONCERNED.....	9
3.2 GLOBAL WARMING POTENTIAL VALUES (GWP).....	9
3.3 TASKS	10
3.4 REGIONALISATION OF EMISSIONS.....	10
4 IMPROVEMENTS.....	11
4.1 IMPROVEMENTS.....	11
4.2 RECALCULATIONS FOR 1995-2015	11
5 EXTERNAL TRADE IN F-GASES	13
6 ANALYSIS BY SECTOR	15
6.1 COOLING APPLICATIONS.....	15
6.1.1 <i>Industrial and commercial</i>	15
6.1.2 <i>Household refrigerators</i>	25
6.1.3 <i>Room air conditioners and heat pumps</i>	28
6.1.4 <i>Air conditioning in private cars</i>	29
6.1.5 <i>Air conditioning in buses and coaches</i>	32
6.1.6 <i>Air conditioning in trucks</i>	34
6.1.7 <i>Air conditioning in rail transport</i>	36
6.1.8 <i>Refrigerated transport</i>	36
6.1.9 <i>Organic Rankine Cycle (ORC)</i>	38
6.1.10 <i>Tractors</i>	39
6.1.11 <i>Reefers</i>	39
6.1.12 <i>Heat pump dryers</i>	40
6.2 FOAMS.....	41
6.2.1 <i>Closed cell foams</i>	41
6.2.2 <i>Polyurethane cans</i>	43
6.2.3 <i>Foams in refrigerators/freezers</i>	43
6.2.4 <i>Disposal emissions</i>	43
6.3 METERED DOSE INHALERS (MDI)	44
6.3.1 <i>Emissions during production</i>	44
6.3.2 <i>Emissions during use</i>	44
6.4 TECHNICAL AEROSOLS	46
6.4.1 <i>Emissions from manufacturing</i>	46
6.4.2 <i>Emissions from use</i>	46
6.5 FIRE EXTINGUISHING	47
6.5.1 <i>Fixed fire extinguisher installations</i>	47
6.6 SOLVENT USES	48
6.6.1 <i>HCFC-141b</i>	48
6.6.2 <i>Other solvents</i>	48
6.7 SEMICONDUCTORS	48
6.8 METHYLBROMIDE.....	49
6.9 SF ₆	50

6.9.1	<i>Glass sector</i>	50
6.9.2	<i>Electricity sector</i>	51
6.9.3	<i>Sport Shoes</i>	52
6.9.4	<i>Other sources of SF6</i>	53
6.10	CHEMICAL INDUSTRY.....	54
7	OVERALL RESULTS.....	56
7.1	EMISSIONS IN TONNES IN 2016	57
7.2	EMISSIONS IN TONNES IN 1995	60
7.3	EMISSIONS IN KT CO ₂ -EQ IN 2016.....	63
7.4	EMISSIONS IN KT CO ₂ -EQ IN 1995.....	66
7.5	EMISSIONS IN KT CO ₂ -EQ IN 1990.....	69
7.6	EMISSIONS IN T CFC-11-EQ IN 2016.....	70
7.7	EMISSIONS IN T CFC-11-EQ IN 1995.....	72
7.8	EMISSION EVOLUTION IN BELGIUM	73
7.8.1	<i>Evolution of emissions by gas</i>	73
7.8.2	<i>Evolution of emissions by source</i>	79
8	UNCERTAINTY ANALYSIS.....	83
8.1	METHODOLOGY.....	83
8.1.1	<i>Introduction</i>	83
8.1.2	<i>Indicators of uncertainty</i>	83
8.1.3	<i>Combination of uncertainties</i>	84
8.1.4	<i>Method retained</i>	86
8.1.5	<i>Trend uncertainties</i>	87
8.2	RESULTS OF THE UNCERTAINTY ANALYSIS.....	87
8.2.1	<i>Introduction</i>	87
8.2.2	<i>Result tables</i>	87
9	REFERENCES.....	97
10	ANNEXES	99
	ANNEX 1: GLOBAL WARMING POTENTIAL (GWP) AND OZONE DEPLETING POTENTIAL (ODP)	99
	ANNEX 2: LIST OF EMISSION SOURCES.....	101
	ANNEX 3: COMMON REPORTING FORMAT (CRF) NOMENCLATURE	102

List of tables

Table 1: Evolution of the Kyoto gas emissions by source, in kt CO ₂ -eq	7
Table 2: Evolution of the emissions of ODS gases by source, in t CFC11-eq.....	8
Table 3: External trade in substances considered.....	14
Table 4: Total supply of refrigerants in Belgium (*).....	17
Table 5: Results of inspection campaigns on refrigeration plants in Flanders	19
Table 6: Leakage by refrigerant on refrigeration plants in Flanders in 2016.....	20
Table 7: Emissions of refrigeration installations by refrigerant (kt CO ₂ -eq)	23
Table 8: Assumptions for household refrigerators and comparison with IPCC 2006 guidelines	27
Table 9: Comparison of assumptions for household refrigerators between selected countries (in 2015)	27
Table 10: Assumptions for room air conditioners and heat pumps and comparison with the IPCC 2006 Guidelines.....	28
Table 11: Comparison of assumptions for room air conditioning and heat pumps between selected countries (in 2015).....	29
Table 12: Assumptions for mobile air conditioners and comparison with IPCC 2006 guidelines	31
Table 13: Comparison of assumptions for car air conditioning between selected countries (in 2015).	32
Table 14: Comparison of assumptions for bus air conditioning between selected countries (in 2015).	33
Table 15: Comparison of assumptions for truck air conditioning between selected countries (in 2015)	34
Table 16: Comparison of assumptions for train air conditioning between selected countries (in 2015)	36
Table 17: Comparison of assumptions for refrigerated transport between selected countries (in 2015)	37
Table 18: Evolution of emissions by substance in Belgium, in tonnes.....	76
Table 19: Evolution of emissions by substance in Belgium, in kt CO ₂ -eq.....	77
Table 20: Evolution of emissions of ozone depleting substances in Belgium, in t CFC11-eq	78
Table 21: Evolution of total emissions per source, in tonnes	79
Table 22: Evolution of CRF gas emissions per source, in kt CO ₂ -eq	80
Table 23: Evolution of the Kyoto gas emissions by source, in kt CO ₂ -eq	81
Table 24: Evolution of the emissions of ODS gases by source, in t CFC11-eq.....	82
Table 25: GWPs and ODPS.....	100
Table 26: List of emission sources with their allocation to the CRF source categories	101
Table 27: Nomenclature of the CRF format	102

Further tables, with detailed results by source and by gas are presented in sections 7.1 to 7.7.

List of figures

Figure 1: Evolution of the Kyoto F-gas emissions per gas category in Belgium (kt CO ₂ -eq)	7
Figure 2: Evolution of ozone depleting substances in Belgium (t CFC11-eq).....	8
Figure 3: Supply of refrigerants in Belgium (tonnes)	18
Figure 4: Supply of refrigerants in Belgium, by substance (tonnes)	18
Figure 5: Percentage controlled installations that were not air tight in Flanders	20
Figure 6: Emissions from refrigeration installations, by substance (t).....	22
Figure 7: Emissions from refrigeration installations, by substance (kt CO ₂ -eq).....	23
Figure 8: Emissions of refrigeration installations by refrigerant (kt CO ₂ -eq)	24
Figure 9: Emissions of Kyoto gases from refrigeration installations, by type (kt CO ₂ -eq).....	24
Figure 10: Emissions from domestic refrigeration (in kt CO ₂ -eq).....	27
Figure 11: Emissions from room air conditioning and heat pumps (in kt CO ₂ -eq).....	28
Figure 12. Stock of cars in Belgium with and without air conditioning	30
Figure 13: Emissions from car air conditioning (in kt CO ₂ -eq).....	32
Figure 14. Stock of buses and coaches in Belgium with and without air conditioning.....	33
Figure 15. Stock of trucks in Belgium with and without air conditioning	35
Figure 16: Emissions from truck air conditioning (in kt CO ₂ -eq)	35
Figure 17. Stock of refrigerated trucks in Belgium.....	37
Figure 18. Market evolution (green, left) and share of each application in terms of number of units (blue, right) [15].	39
Figure 19. Emissions from heat pump tumble driers (in kt CO ₂ -eq)	41
Figure 20: Consumption of F-gases for foam manufacturing (t).....	42
Figure 21: Emissions of F-gases from foams (kt CO ₂ -eq).....	42
Figure 22: Number of MDI doses sold in Belgium (million)	44
Figure 23: Quantity of F-gases in MDIs sold in Belgium (t)	45
Figure 24: Emissions from the use of MDIs (kt CO ₂ -eq)	45
Figure 25: Emissions from the use of technical aerosols (kt CO ₂ -eq.).....	47
Figure 26: CRF gas emissions from fire extinguishers (kt CO ₂ -eq.)	48
Figure 27: Emissions from semiconductor industry (in kt CO ₂ -eq)	49
Figure 28: Emissions of methyl bromide (t)	50
Figure 29. SF ₆ emissions from double glass in Belgium (in kt CO ₂ -eq).	51
Figure 30. SF ₆ bank (in t) in switchgear in Belgium at the end of the year.	52
Figure 31: Emissions from chemical industry (in kt CO ₂ -eq)	55
Figure 32: Evolution of the F-gas emissions by type of gas in Belgium (tonnes)	73
Figure 33: Evolution of the F-gas emissions by substance in Belgium (tonnes)	74
Figure 34: Evolution of the F-gas emissions per gas category in Belgium (kt CO ₂ -eq)	74
Figure 35: Evolution of the Kyoto F-gas emissions per gas category in Belgium (kt CO ₂ -eq)	75
Figure 36: Evolution of the Kyoto F-gas emissions per substance in Belgium (kt CO ₂ -eq).....	75
Figure 37: Evolution of ozone depleting substances, by gas category, in Belgium (t CFC11-eq)	78
Figure 38: Evolution of ozone depleting substances, by substance, in Belgium (t CFC11-eq) ...	79
Figure 39: Evolution of Kyoto gas emissions by source (kt CO ₂ eq)	80
Figure 40: Evolution of ODS gas emissions by source (t CFC11-eq)	81

1 EXECUTIVE SUMMARY

The present study has consisted in updating for the years 1995-2016 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 39 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.

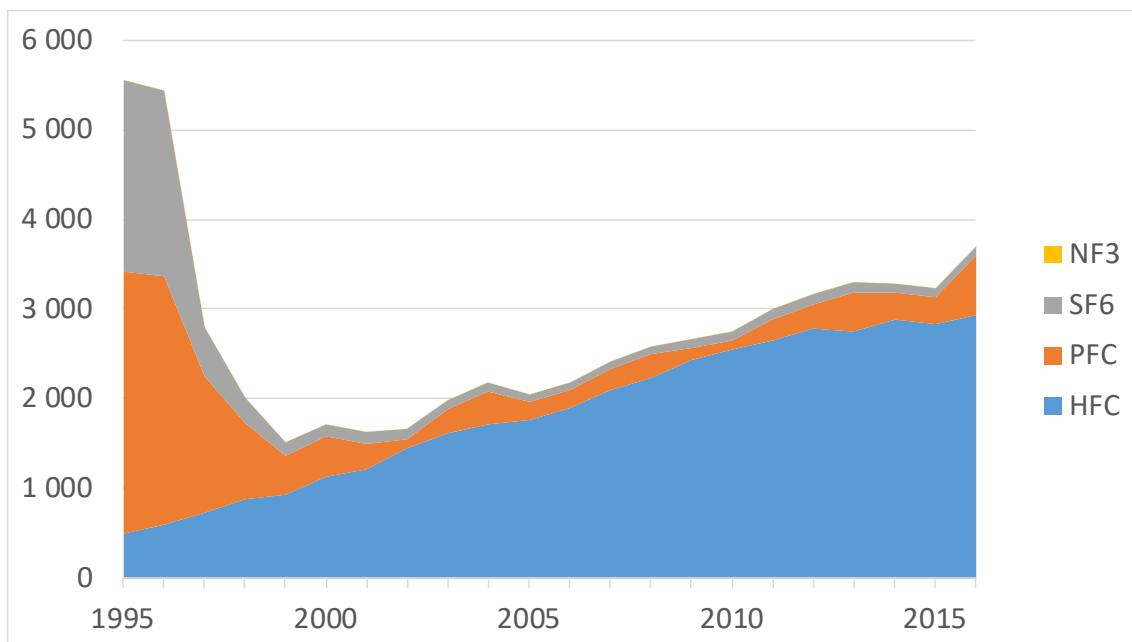


Figure 1: Evolution of the Kyoto F-gas emissions per gas category in Belgium (kt CO₂-eq)

The dominating contribution is that of hydrofluorocarbons (HFCs), which still showed a rising trend, as these substances replace ozone depleting substances (ODS). The main emission sources are stationary refrigeration and air conditioning ('Commercial refrigeration'), as well as mobile air conditioning.

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

(kt CO ₂ -eq)	CRF Name	1995	2000	2005	2010	2013	2014	2015	2016
2 B 9	Fluorochemical production	4 919,6	445,9	175,6	96,7	422,7	299,6	293,1	645,7
2 E 1	Integrated circuit or semiconductor			17,8	13,0	11,8	11,9	13,0	22,7
2 F 1 a	Commercial refrigeration	75,0	630,0	1 206,5	1 773,3	1 967,0	2 059,6	2 005,8	2 099,2
2 F 1 b	Domestic refrigeration	0,1	0,4	0,6	2,0	2,1	2,1	2,1	1,3
2 F 1 d	Transport refrigeration	1,5	10,6	26,6	41,3	40,8	44,0	36,8	30,0
2 F 1 e	Mobile air-conditioning	26,6	147,1	307,9	515,1	585,1	613,4	612,8	609,8
2 F 2 a	Closed cell foam	356,8	268,1	122,2	119,5	60,7	65,0	70,8	92,1
2 F 3	Fire protection	0,6	4,9	12,4	14,0	12,0	12,5	13,3	12,9
2 F 4 a	Metered dose inhalers			0,4	39,7	46,2	48,4	48,6	48,8
2 F 4 b	Other aerosols (technical aerosols)	41,5	70,3	50,3	34,6	34,0	33,2	41,1	42,3
2 G 1	Electrical equipment	7,8	9,3	10,8	12,9	12,4	11,4	9,9	10,6
2 G 2 c	Soundproof windows	79,8	87,8	69,9	86,2	101,0	80,4	78,9	77,4
2 G 2 d	Adiabatic properties: shoes and tyres	46,9	47,0	8,0					
Total		5 556,0	1 721,6	2 048,1	2 754,8	3 298,1	3 281,5	3 226,2	3 693,1

(*) This category also includes industrial refrigeration, stationary air conditioning and heat pumps

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).

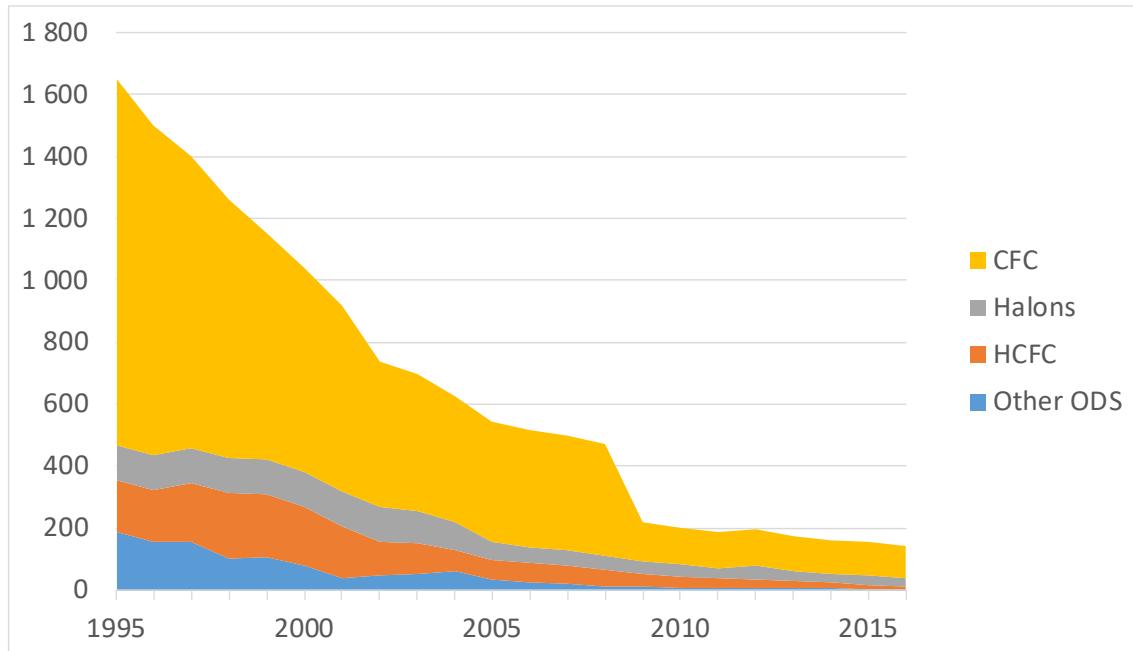


Figure 2: Evolution of ozone depleting substances in Belgium (t CFC11-eq)

As shown in Table 2, the dominant source of ODS gas emissions is insulation foam.

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

(t CFC-11 eq)	1995	2000	2005	2010	2013	2014	2015	2016
01. Dom. refriger. - Coolant	47,30	44,98	28,13					
02. Dom. refriger. - Foam	286,07	282,04	210,65	0,00	0,00			
03. RAC & heat pumps	1,14	3,74	2,14					
04. Car airco	13,91							
05. Bus&Coach airco	13,78							
10. Ind.&comm. refriger.	645,23	178,48	56,04	24,59	14,65	6,92	3,40	1,00
11. Closed cell foam	268,51	250,53	145,27	130,51	123,16	120,83	118,57	116,36
13. Aerosols MDI	69,39	66,20	4,94	0,06	0,00			
15. CCl4	32,10	0,74	0,74	0,74	0,74	0,74		
16. Methylbr.	154,76	76,99	34,38	6,36	5,19	4,48	2,38	1,29
19. Fire Extinguishers	112,95	112,95	61,41	40,57	29,66	28,19	29,44	23,94
21. Semiconductors	0,00			0,00	0,00			
23. Solvents	5,50	24,75	1,65					
Total	1 650,65	1 041,41	545,37	202,84	173,42	161,18	153,79	142,59

2 INTRODUCTION

The present study has consisted in updating for the years 1995-2016 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.

3 WORK PROGRAMME

The inventory has been established according to the new 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].

3.1 Gases concerned

The updated inventory system considers 50 gases:

- the 30 compulsory gases of the new UNFCCC reporting (19 HFCs, 9 PFCs, SF6 and NF3);
- 12 ODS 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, 39 have non-zero emission values.

3.2 Global Warming Potential values (GWP)

In accordance with Decision 24/CP.19 of the Conference of the Parties to the UNFCCC, the GWP values used for the CRF gases are those listed in Annex III of this decision, which are the 100-year lifetime values 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].

¹ FCCC/CP/2013/Add.3.

3.3 Tasks

The inventory is set up in a manner consistent with those of the previous years, using the methodology first developed by ECONOTEC in 1999 [5] and later improved and enhanced in collaboration with VITO during the annual updates.

The same methodology has been applied for all years from 1995 to 2016. Where improvements have been made to the methodology or to emission factors, or if a new source is added, recalculations have been made.

Except for the contribution to the National Inventory Report, which will be prepared in due time for the UNFCCC reporting of March 2018, 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 2016
 - Update and optimisation of the emission estimates for the period 1995-2015
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 2016, as well as update of the uncertainty analyses for 1995 and 2015
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 particular regions, they are attributed to these regions (e.g.: emissions of 'chemical industry', manufacturing emissions of foams or aerosols).
- Other 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:

- External trade statistics: from 2016, Eurostat import and export statistics are available for 12 new product categories (individual substances or mixtures of HFCs, PFCs and HFOs). They have been taken up in this report.
- For refrigeration and air-conditioning ‘installations’:
 - Revision of the assumptions on the refrigerant shares for new systems, taking into account the penetration of natural refrigerants;
 - Introduction of retrofitting of R404A in existing systems;
 - Re-examination of the evaluation of the amount of refrigerant in systems at time of disposal and of the disposal emissions, based on consultations.
- Room air-conditioning and heat pumps: re-examine the breakdown into types, eg. Air-conditioning, heat pumps (taking into account the note of VEA on heat pumps). We analysed the VEA report and concluded that the data are in line with our assumptions. The split between air conditioning and heat pumps is difficult and reliable statistics are not available to make it. We continued using the data of UBF-ACA and assumptions on the division between movable – split – multisplit – heat pump boilers. Fugitive emission factors were adjusted.
- Refrigerated transport: evaluation of assumptions about refrigerant use in new trucks. This has led to a change in the assumptions and an insight into future use of R404a and R452a in refrigerated transport in the upcoming years.
- Other transport: Estimate of emissions from other modes of transport (refrigerated containers, etc.), which are now comprised in emissions from installations. Added a first assessment for tractors and reefers.
- Reallocation of ‘canister foam’ from ‘closed cell foam’ to ‘PU cans’ and revision of its emission factors and export assumptions
- Revision of emission factors and export assumptions for 2-component spray foam
- Addition of some of the additional emission sources to the CRF reporting.

4.2 Recalculations for 1995-2015

The following recalculations have occurred compared with the previous inventory:

- 2 B 9 Fluorochemical production: revised figures for 2015 (impact on CO₂-eq emissions: +9,2%)
- 2 F 1 a Commercial refrigeration: figures were adapted from 1998 to 2015; the largest change is reached for 2015 (impact: +2,3%)
 - For the category ‘room air conditioners and heat pumps’, heat pump boilers were added, and fugitive emission factors were adjusted for larger installations
 - Improvements for ‘installations’ (see par. 4.1 above)
- 2 F 1 d Transport refrigeration: assumptions on the load and share of R134a and R404a in the smallest weight category have been revised, from 2011 to 2015 (impact: -20,7% in 2015)
- 2 F 1 e Mobile air-conditioning: revision for 2015 (impact: -0,4%)

- 2 F 2 a Closed cell foam: 2009 to 2015 (impact for 2015: -6,7%)
- 2 F 4 b Other aerosols (technical aerosols): adjustment of manufacturing and fugitive emissions for 2014 and 2015 because of new information (impact: +35% in 2015)

5 EXTERNAL TRADE IN F-GASES

Official statistics on external trade are only available for a limited number of substances. 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, 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 3. Note that the figures for 2015 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).

As far as refrigerant R22 is concerned, one can notice that its trade in 2013 (import of 1547 t, export of 1453 t) is very large compared to the apparent net consumption (46 t in 2014) and that this net consumption differs from the amount delivered as refrigerant according to our survey (40 tonnes).

In 2016, one can still notice a large trade in refrigerant R22 (import of 1396 t, export of 1789 t), but with a (much smaller) net export (93 t), which is consistent with the 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.

Table 3: External trade in substances considered

(tonnes)	Import						Export						Net import											
	2000	2010	2012	2013	2014	2015	2016	2000	2010	2012	2013	2014	2015	2016	2000	2010	2012	2013	2014	2015	2016			
CCl4	891	2,8	0,1	0,0	0,4	0,0	0,0	442	0,1	1,5	-	0,0	-	-	449	3	-1	0	0	0	0,0			
1,1,1-trichloroethane	22	190,7	238,9	259,3	233,2	236,4	-	38	121,0	141,0	148,8	134,2	151,9	-	-16	70	98	111	99	85	0,0			
methylbromide	6 721	3 999,0	1 418,4	1 572,9	1 168,3	243,7	253,2	3 313	1 719,0	997,2	1 139,6	689,4	160,0	374,2	3 408	2 280	421	433	479	84	-121,0			
CFC 11	2 306	0,0	0,0	0,0	0,0	0,0	n.a.	247	-	-	-	-	-	n.a.	2 059	0	0	0	0	0	0 n.a.			
CFC 12	674	1,1	2,5	2,0	1,0	0,0	n.a.	569	0,2	0,4	0,6	0,8	-	n.a.	105	1	2	1	0	0	0 n.a.			
CFC 113	33	13,2	0,0	0,0	0,9	3,9	n.a.	29	-	-	-	-	0,4	n.a.	4	13	0	0	1	4	n.a.			
CFC 114	13	-	-	-	-	-	n.a.	6	-	-	-	-	-	n.a.	7	0	0	0	0	0	0 n.a.			
CFC 115	1	-	-	-	-	-	n.a.	1	-	-	-	-	-	n.a.	0	0	0	0	0	0	0 n.a.			
CFC 11 to 115	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	4,1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0,5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	3,6			
CFC 13	2	-	n.a.	n.a.	n.a.	n.a.	n.a.	0	-	n.a.	n.a.	n.a.	n.a.	n.a.	2	0	n.a.	n.a.	n.a.	n.a.	n.a.			
CFC 111	-	-	n.a.	n.a.	n.a.	n.a.	n.a.	-	-	n.a.	n.a.	n.a.	n.a.	n.a.	0	0	n.a.	n.a.	n.a.	n.a.	n.a.			
(CFC112)	-	-	n.a.	n.a.	n.a.	n.a.	n.a.	-	-	n.a.	n.a.	n.a.	n.a.	n.a.	0	0	n.a.	n.a.	n.a.	n.a.	n.a.			
halon 1211	-	0,2	-	-	-	21,0	-	-	16,1	6,7	26,5	34,1	37,9	2,1	0	-16	-7	-27	-34	-17	-2,1			
halon 1301	0	-	-	-	-	-	-	-	6,5	-	-	-	4,3	-	0	-7	0	0	0	0	-4	0,0		
halon 2402	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0,0			
HCFC 22	n.a.	4 702	1 451,1	1 546,8	2 164,7	1 836,7	1 696,1	n.a.	4 763	1 183,1	1 444,2	2 134,6	1 936,6	1 788,9	n.a.	-61	268	103	30	-100	-92,8			
HCFC 123	n.a.	n.a.	1,3	-	-	-	-	n.a.	n.a.	7,0	-	-	-	-	n.a.	n.a.	-6	0	0	0	0	0,0		
HCFC 141	n.a.	n.a.	0,8	-	0,0	-	-	n.a.	n.a.	-	-	1,3	17,2	-	n.a.	n.a.	1	0	-1	-17	0,0			
HCFC 142	n.a.	n.a.	228,1	43,5	27,3	-	324,2	n.a.	n.a.	-	-	-	-	0,5	n.a.	n.a.	228	44	27	0	323,7			
HCFC 225	n.a.	n.a.	3	22	0	-	-	n.a.	n.a.	0	32	0	-	0,0	n.a.	n.a.	3	-10	0	0	0	0,0		
HFC 32	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1,9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	127,1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-125,2			
HFC 23	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	8,4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2,8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	5,6			
HFC 125, HFC 143a	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0,0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	178,4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-178,4			
HFC 152a	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	151,6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	11,2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	140,4			
HFC 134a	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1 645,3	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1 349,5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	295,8			
PFCs	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	178,9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	39,0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	139,9			
HFO 1234yf	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	90,8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	127,3	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-36,5			
HFO 1234ze	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	67,7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	44,7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	23,0			
mixtures with CFC	n.a.	n.a.	n.a.	n.a.	120,4	104,8	47,6	n.a.	n.a.	n.a.	23,2	4,0	0,5	n.a.	n.a.	n.a.	n.a.	97	101	47,1				
mixtures with HCFC	n.a.	n.a.	n.a.	n.a.	0,1	0,0	70,1	n.a.	n.a.	n.a.	6,1	44,4	52,9	n.a.	n.a.	n.a.	n.a.	-6	-44	17,2				
mixtures with PFC/HFC	n.a.	n.a.	n.a.	n.a.	4 108,9	4 854,8	n.a.	n.a.	n.a.	n.a.	3 412,2	4 266,0	n.a.	n.a.	n.a.	n.a.	697	589	0,0					
HFC 507A	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	347,6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	383,8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-36,2			
HFC 404A	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1 310,6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1 317,7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-7,1			
HFC 410A	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	3 396,6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1 870,8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1 525,8			
HFC 407C, HFC 407A, HFC 407F	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	557,7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	592,0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-34,3			

Source : Eurostat

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

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, commercial and stationary air conditioning installations,
- household refrigerators,
- refrigerated transport,
- air conditioning of private cars,
- air conditioning of buses and coaches,
- trucks air conditioning,
- passenger rail transport air conditioning.

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

Industrial and commercial 'installations' represent all on-site assembled systems for industrial & commercial refrigeration as well as stationary air-conditioning applications. They are the largest single source of F-gas emissions and are reported 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 is subtracted. Assumptions are made on the average loss rates. No distinction is made between industrial refrigeration, commercial refrigeration and air conditioning 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 for National GHG Inventories, 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).

The recovery efficiency of disposal is assumed to be 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%).

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”. For R404A, the main refrigerant used in refrigeration installations, the total amount recovered over the period 1998-2016 was 110 tonnes, while the corresponding total “amount in systems at time of disposal” was estimated at 411 tonnes, which corresponds to a recovery efficiency of 27%².

² Note that, for reasons of consistency the value of the recovery ratio had been revised downwards from 50% for the 2016 submission of the national GHG inventory, after an upward reassessment of the ‘Amount charged into new systems’ for HFCs, and, consequently, of the ‘Amount in systems at time of disposal’.

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. In this latest survey, the refrigerants R32 and R474A were added.

All the companies have responded. The results of the survey up to 2016 are shown in Table 4, and in graphical form on Figure 3 and Figure 4.

Table 4: Total supply of refrigerants in Belgium (*)

(tonnes)	2003	2005	2010	2011	2012	2013	2014	2015	2016
R22	655,2	506,6	113,5	94,3	61,4	40,0	20,0	0,0	0,0
R32	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,5
R134a	296,6	335,3	413,2	448,3	438,1	399,3	467,2	413,4	396,3
R404A	261,0	308,5	322,2	332,4	290,9	300,0	281,1	240,0	186,2
401A	7,3	3,6	0,0	0,0	0,0	0,0	0,0	0,0	0,0
402A	2,4	2,0	0,0	0,6	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
R407C	79,0	80,2	96,9	83,7	70,7	75,3	76,1	79,6	66,2
408A	21,6	16,1	0,0	0,2	0,2	0,1	0,0	0,0	0,0
409A	56,9	38,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0
R410A	9,2	22,1	88,2	87,1	96,7	88,3	85,4	126,4	116,0
R413A	12,3	6,4	0,9	0,4	0,3	0,3	6,1	0,0	0,1
R507A	59,7	77,2	133,7	115,4	115,7	112,1	114,7	91,2	79,2
R417A	0,0	3,9	11,1	6,4	3,3	13,4	7,8	5,9	3,1
R422D	0,0	0,0	16,8	25,7	18,8	18,7	27,9	28,2	22,9
R427A	0,0	0,0	7,5	6,1	6,1	6,7	6,9	7,1	4,0
R422A	0,0	0,0	0,0	5,1	4,5	3,1	0,6	3,1	1,7
R407A	0,0	0,0	0,0	0,0	0,0	1,0	2,9	0,8	1,8
R407F	0,0	0,0	0,0	0,0	0,0	9,1	28,8	40,1	34,9
R434A	0,0	0,0	0,0	0,0	0,0	0,0	3,0	4,0	0,0
R437A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5
R508A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
R508B	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
R448A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,0	6,0
R449A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	13,0	37,5
R450A	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0
R1234yf	0,0	0,0	0,0	0,0	0,0	2,0	2,2	2,4	6,9
TOTAL	1462,5	1402,1	1204,2	1205,7	1106,6	1069,2	1130,6	1058,3	965,7

(*) Excluding supply to original equipment manufacturers (OEM)

The latest survey confirms the steady decline in the overall supply that has taken place since 2006 (with the exception of 2014, where there has been a 5,5% rise, due to R134a).

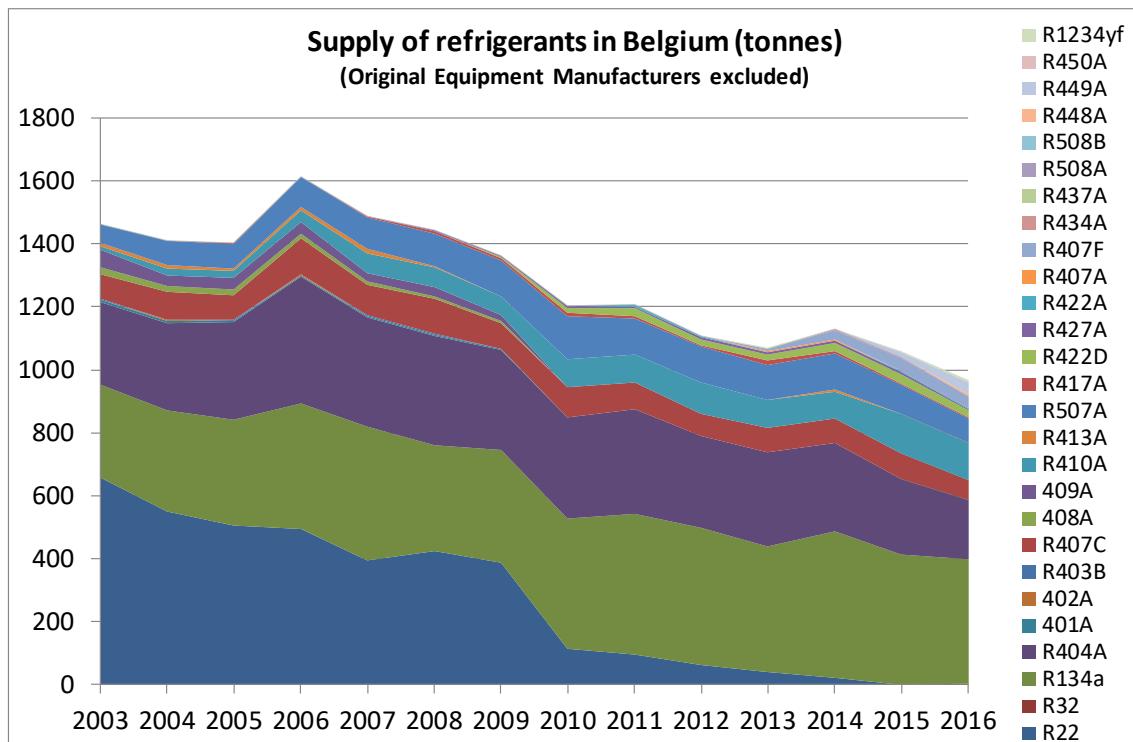


Figure 3: Supply of refrigerants in Belgium (tonnes)

The evolution by individual refrigerant is displayed on Figure 3. One can notice the erosion of R404A, R507A and R134a and the penetration of R449A, a substitute for R404A, in 2016.

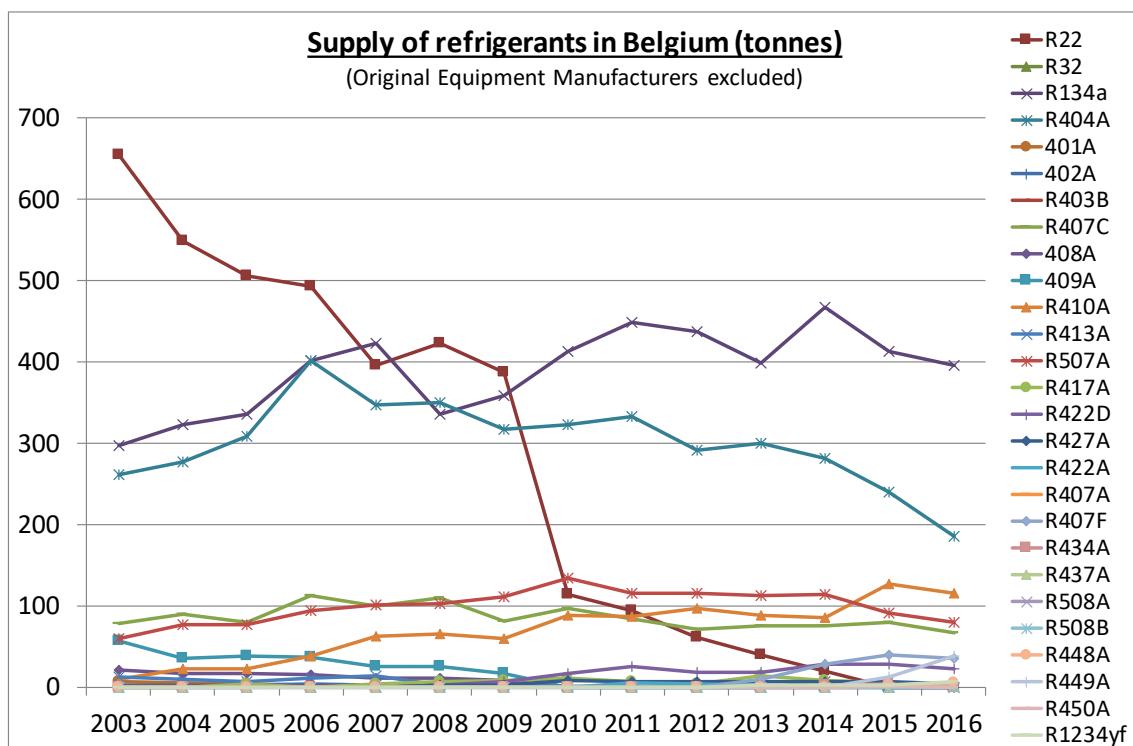


Figure 4: Supply of refrigerants in Belgium, by substance (tonnes)

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 bank³ 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 (see Table 5 and Figure 5). Leakages still occur at a significant fraction of the investigated plants (in 2016, 43% of the inspected plants still had leakages), but there has on average been a decreasing trend over the last 8 years. It should be noted that the installations concerned are not necessarily representative of the existing stock of installations and that inspections have tended to focus on plants that are more likely to be leaking.

Table 5: Results of inspection campaigns on refrigeration plants in Flanders

Cooling systems tested on behalf of Milieu-Inspectie		
Year	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

³ 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.

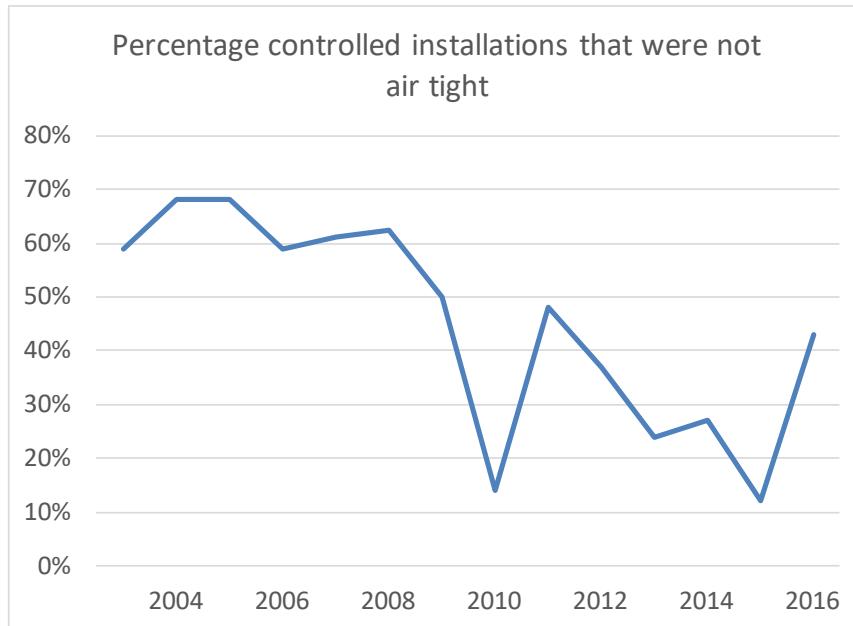


Figure 5: Percentage controlled installations that were not air tight in Flanders

Table 6: 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: Milieuhandhavingrapport 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:

- 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 8,8% in 2016.

In the framework of the consultations mentioned under par. 4.1, which we held with service companies, operators, refrigerant suppliers and experts in the field of refrigeration or air-conditioning, this topic was also addressed. From these consultations, 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 8.2, 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 517/2014⁴ and its enforcement by regional governments.

6.1.1.3 Improvements made

The following improvements have been made:

- Penetration of natural refrigerants in new systems:
 - The current estimates are multiplied by an ‘F-gas fraction’, linearly varying from 100% in 2006 to 75% in 2016, to take into account the penetration or increased penetration of NH₃ 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 [6]).
- Revision of the F-gas refrigerant mix for new systems, by increasing the shares of R448A and R449B, based on the overall supply of these refrigerants and a fraction of retrofitting.
- Introduction of R404A retrofit in existing systems, based on refrigerant supplies (small impact):
 - A certain amount of retrofit of R404A and its replacement by R407F, R448A and R449A is assumed, based on the total supply of the latter refrigerants.

As a result of the first two changes, the consumption of R404A in new systems now decreases by 63% from 2008 to 2016.

⁴ 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.

It should be noted that, except for the manufacturing emissions, which are marginal, these changes have 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.

6.1.1.4 Results

While total emissions of installations have been strongly declining, those of HFCs are still rising.

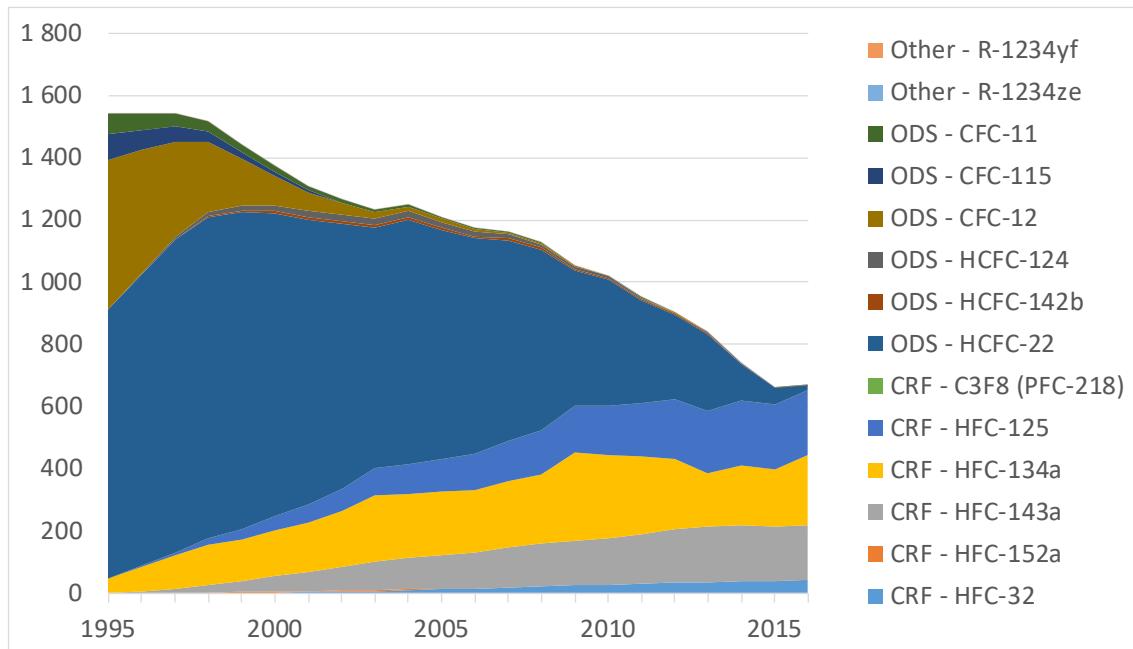


Figure 6: Emissions from refrigeration installations, by substance (t)

As shown in Figure 7, the emissions expressed in CO₂ equivalents decline even more strongly up to 2001, as CFC-12, which has a very high GWP (8100) is being phased out. The decline in 2015 is mainly the result of a higher recovery of R22.

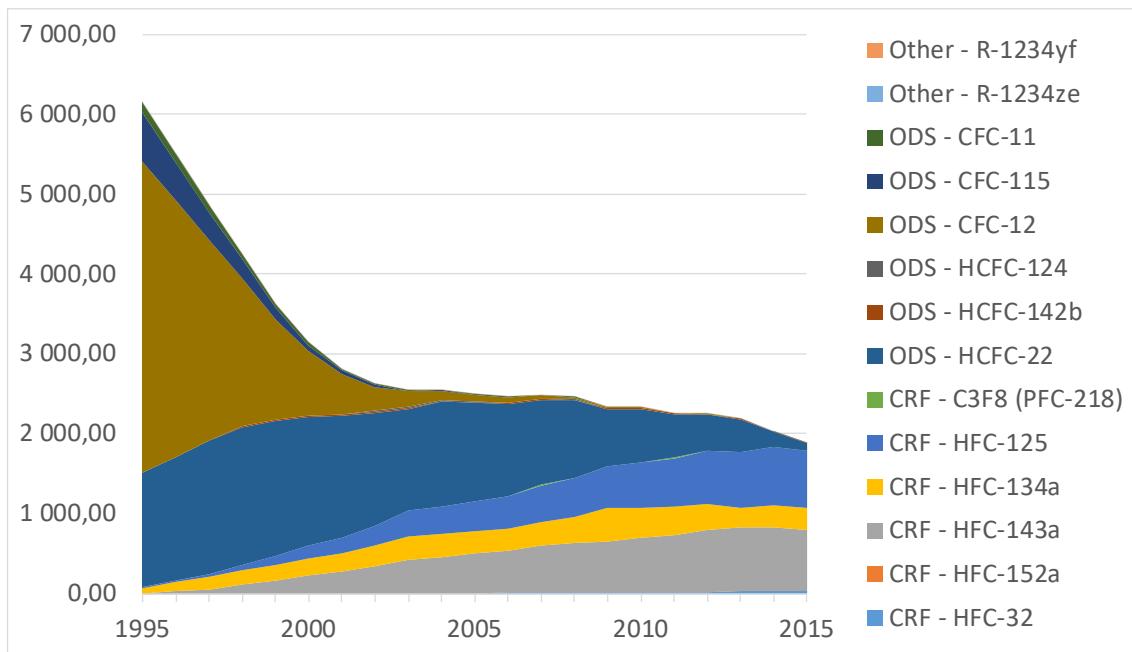


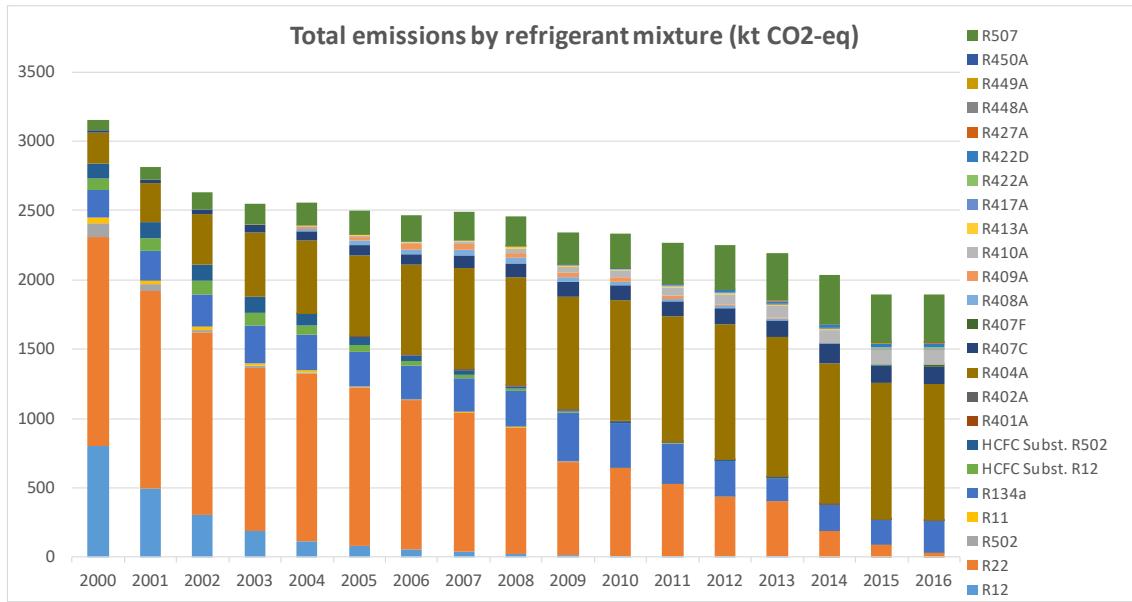
Figure 7: Emissions from refrigeration installations, by substance (kt CO₂-eq)

Table 7 and Figure 8 show the total emissions by refrigerant, in terms of CO₂ equivalents.

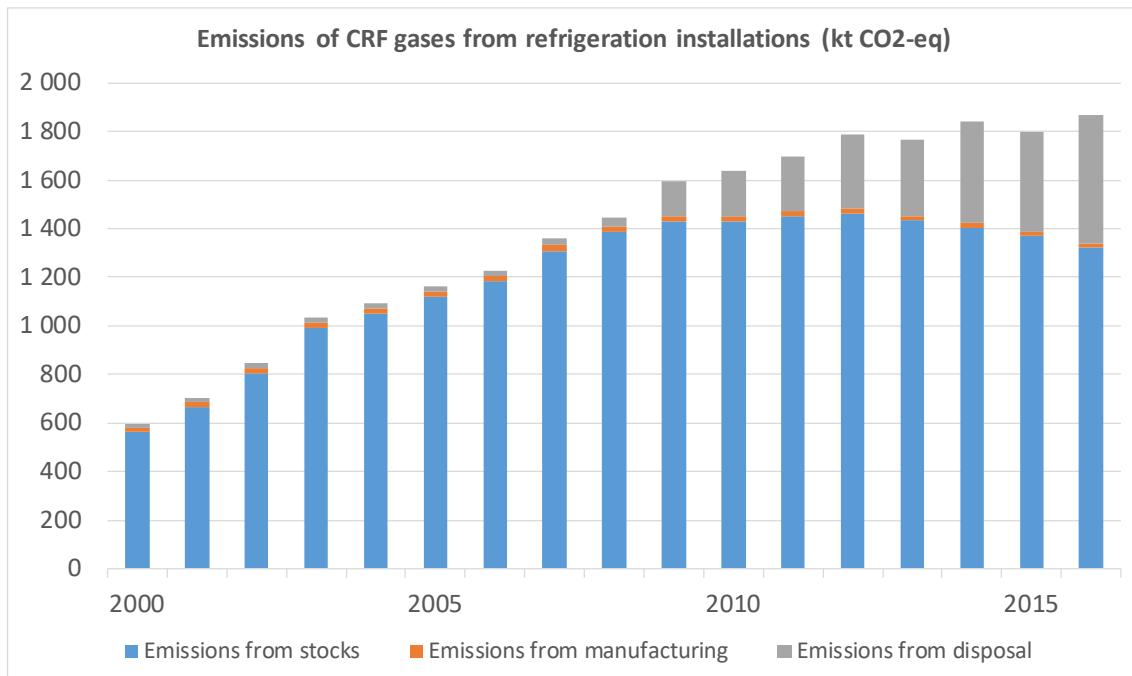
Table 7: Emissions of refrigeration installations by refrigerant (kt CO₂-eq)

(kt CO ₂ -eq)	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
ODS	6 082,3	2 555,0	1 340,6	695,7	567,0	464,6	422,6	198,8	95,3	29,2
CFC-11	134,1	38,7	8,2	1,1	0,8	0,6	0,5	0,2	0,2	0,0
CFC-12	3 910,1	798,1	83,6	10,9	8,1	5,7	4,7	2,4	1,7	0,3
CFC-115	604,4	80,3	4,5	0,6	0,4	0,3	0,3	0,1	0,1	0,0
HCFC-124		8,6	8,2	3,5	2,6	1,9	1,5	0,8	0,5	0,1
HCFC-142b		11,3	12,7	6,6	4,9	3,5	2,8	1,4	1,0	0,2
HCFC-22	1 433,9	1 618,1	1 223,4	672,9	550,2	452,7	412,9	193,8	91,8	28,7
CRF	74,9	594,7	1 159,8	1 637,5	1 696,8	1 786,4	1 767,8	1 839,3	1 796,8	1 865,2
HFC-125	4,0	161,0	371,7	559,7	605,8	666,0	700,7	727,8	720,6	733,9
HFC-134a	64,8	210,5	289,6	380,2	355,2	325,1	244,5	275,0	263,0	322,6
HFC-143a	6,0	221,2	488,2	676,6	713,0	770,7	796,1	808,0	784,0	777,5
HFC-152a		0,4	0,3	0,1	0,0	0,0	0,0	0,0	0,0	0,0
HFC-32		1,7	7,8	17,7	19,9	22,0	24,4	26,5	27,2	29,4
C3F8 (PFC-218)		2,2	3,2	2,8	2,4	2,1	1,9	2,1	1,8	
Other									0,0	0,0
R-1234yf									0,0	0,0
R-1234ze								0,0	0,0	
General total	6 157,2	3 149,7	2 500,4	2 333,1	2 263,7	2 251,0	2 190,4	2 038,1	1 892,1	1 894,4

Dominant are R22 in the first place, and later R404A/R507 progressively replacing it.

**Figure 8: Emissions of refrigeration installations by refrigerant (kt CO2-eq)**

The emissions of Kyoto gases, expressed in CO2-eq are still increasing in 2015 (Figure 9). This is because of an increasing share of disposal emissions. It should be recalled that there remains a high uncertainty on the level of the latter emissions. They are assessed from the ‘amount in systems at time of disposal’ (based on assumed consumptions in new equipment, average equipment lifetime and percentage remaining in systems at time of disposal) and the recovery rate.

**Figure 9: Emissions of Kyoto gases from refrigeration installations, by type (kt CO2-eq)**

At the request of the steering group, we have re-examined the evaluation of the amount of refrigerant in systems at time of disposal and of the disposal emissions, based on consultations with service companies, operators, refrigerant suppliers and experts.

The ‘amount in systems at time of disposal’ would be overestimated if the refrigerant bank is overestimated. This would imply that the yearly emission rate is underestimated. Nobody knows what the actual average yearly emission rate is, and there is no common view about it among professionals, who tend to have diverging (partial) evidence to mention about it. Divided by population, the Belgian HFC refrigerant bank in stationary refrigeration and air-conditioning applications is 15% higher than the average in its neighbouring countries (D, F, UK, NL), with large differences among countries, Germany being 27% lower, and the UK 32% higher, than the average⁵. Roughly, should we assume for Belgium the average bank per inhabitant of our neighbouring countries, the ‘amount in systems at time of disposal’ would be 13% lower and the disposal emissions 17% smaller.

Besides, up to 2006 there does not seem to have been a significant amount of recycling of refrigerants (in the sense of EU Regulation 517/2014, not to be confused with ‘reclamation’).

Given the remaining uncertainty and the lack of evidence against our assumptions, we have kept our calculation for the time being.

6.1.2 Household refrigerators

For the calculation, household refrigerators comprise and are divided into three categories: independent refrigerators, independent freezers and refrigerator/freezers.

The number of new household refrigerators and freezers is calculated based on the stock of equipment and the estimated number of end-of-life refrigerators. No sale statistics for Belgium are readily available. Of the new refrigerators and freezers, it is assumed that none use HFC-134a as cooling agent and HFC-245fa in foam in 2015. As there is no manufacturing in Belgium, manufacturing emissions are zero.

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 survey⁶, we do not use the household budget enquiry but assume a linear extrapolation of the percentage ownership between 2010 and 2014 for all three types of equipment. To calculate the number of refrigerators and freezers, the percentage ownership is multiplied with the number of households. The number of households in Flanders, Wallonia and Brussels for 2010 - 2016 was completed with information from the Federal Planning Bureau.

Because no new equipment containing HFCs is placed on the market from 2015, assumptions relating to the stock of equipment is not relevant anymore in the calculation of the emissions.

⁵ According to the 2017 national CRF submissions to the UNFCCC for 2015.

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

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

**EQUATION 7.13
SOURCES OF EMISSIONS DURING EQUIPMENT LIFETIME**

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

Where:

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

B_t = amount of HFC banked in existing systems in year t (per 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

Refrigerators and freezers have an average life-time 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 2015 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 type of substances and therefore cannot be used.

Emissions from disposal (see IPCC methodology below) can occur at two different stages of the process: 1) at home, during collection, storage and transport from the collector to the dismantling plant; and 2) at the dismantling plant. The emission factor for the first type of emissions is currently assumed to be 20% and occurs at the region where refrigerators and freezers originate from. To our knowledge, there are no published studies that have estimated these emissions and Recupel nor Coolrec could provide an estimate. We have therefore kept the emission factor of 20%, which can be reviewed in future when information becomes available.

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

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

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 2016.

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 20% 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 household refrigerators between selected countries (in 2015)

Assumption	BELGIUM	FRANCE	GERMANY	UK
Disposal EF (%)	28%	60%	27%	30%
Fugitive EF (%)	1%	0,01%	0,30%	0,30%
Manufacturing EF (%)	NO	NA	NO	0,60%
Lifetime (y)	15	15	15	15
Charge (g)	100	46 - 60	NR	100
share R134a (%)	0%	1%	NR	NR

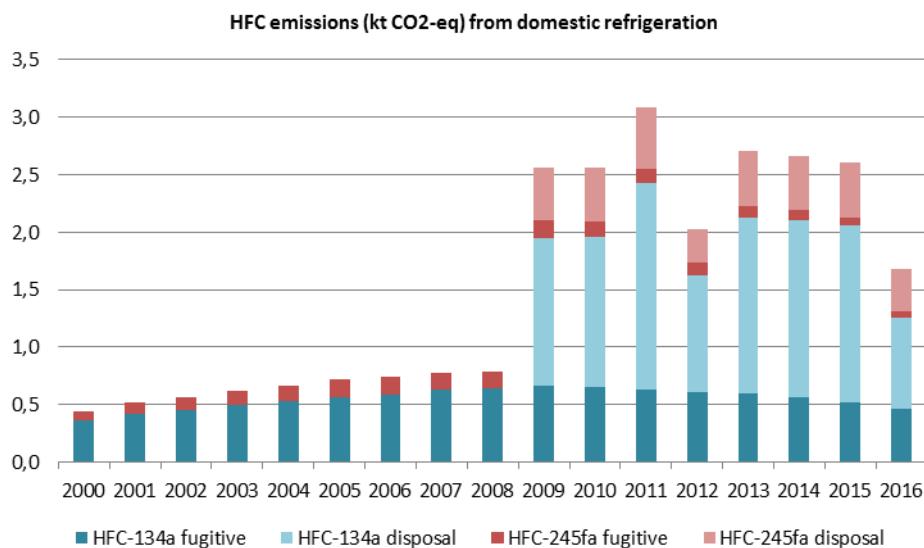


Figure 10: Emissions from domestic refrigeration (in kt CO2-eq)

6.1.3 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 2016.

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 2005-2016. For 2012-2016 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.

Based on these data and assuming an average lifetime of 15 years, the total stock of equipment in Belgium is calculated. Assumptions made by [7] were used to estimate the quantity of refrigerants per unit.

The disposal emissions are assumed to be 70%, based on [8].

Table 10: 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.

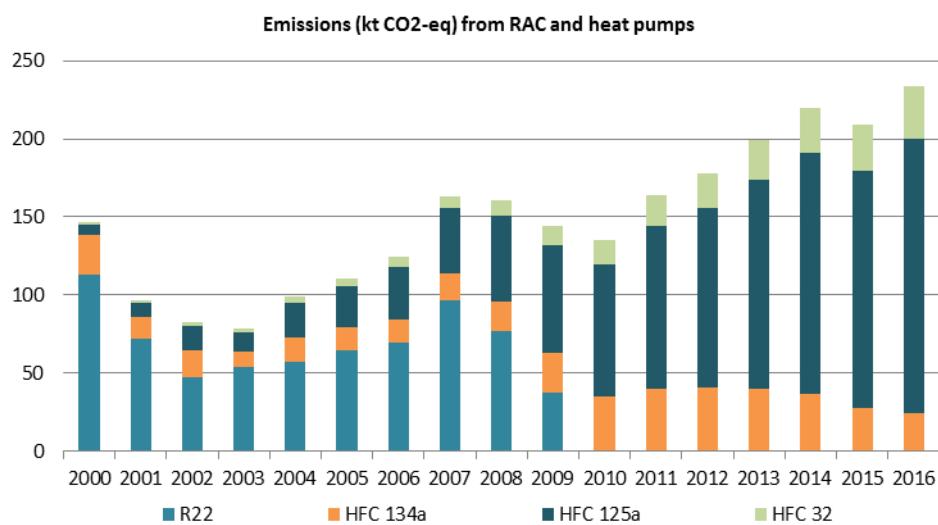


Figure 11: Emissions from room air conditioning and heat pumps (in kt CO2-eq)

Table 11: Comparison of assumptions for room air conditioning and heat pumps between selected countries (in 2015)

indicator	BELGIUM	FRANCE	GERMANY	UK
Manufacturing EF (%)	0,07%	NR	0,5 - 10%	0,5 - 1%
Charge (kg)	0,5 - 6,2 kg	0,5 - 15 kg	NR	1,8 - 15 kg
movable: Share R290 (%)	28%	10%	NR	NR
movable: Share R407c (%)	3%	0%	NR	NR
movable: Share R410a (%)	69%	90%	NR	NR
split: Share R32 (%)	0,30%	5%	NR	NR
split: Share R407c (%)	2,90%	1%	NR	NR
split: Share R410a (%)	97%	94%	NR	NR
multisplit: Share R32 (%)	0%	5%	NR	NR
multisplit: Share R407c (%)	3%	1%	NR	NR
multisplit: Share R410a (%)	97%	94%	NR	NR
Lifetime (y)	15	10 - 15	10 - 15	13 - 18
Fugitive EF – movable (%)	2,5%	2%	2,50%	5 - 6%
Fugitive EF – split (%)	4%	4%	5%	5 - 6%
Fugitive EF – multisplit (%)	5%	5%	5 - 6%	5 - 6%
Disposal EF (%)	70%	30 - 82%	33 - 75%	18 - 25%

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 2016 and their emissions. One company reports technical emission factors, while another reports differences between purchased and used quantities, resulting in higher emission factors.

Data on the total number of cars produced in Belgium over the past year were obtained from FEBIAC [9] and the number of new cars registered in Belgium from the national statistics office [10].

To calculate the emissions from car air conditioning systems, the share of new cars equipped with air conditioning systems must be known. For 2016, this share is estimated to be 96%. This is based on Schwartz [11], who reported that in 2008 the number of new cars with air conditioning appeared to have reached a plateau at 96%. We have assumed that in Belgium this value was reached in 2010. Schwartz [11] reported this as a saturation level, assuming that this is a maximum. 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 lifted⁷. 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 [12]. In Belgium, we assume that 1,4% of cars sold in 2013 contain HFO-1234yf⁸, 6% in 2014, 24% in 2015 and 82% in 2016 taking into account a gradual increase in number of cars.

It is assumed that CO₂ has not been used in car mobile air conditioning systems. Mercedes and VW have announced to start with using CO₂ as coolant. Mercedes however announced that CO₂ will only be used in top-range models (HFO-1234yf in other models). VW also announced that installation of CO₂ air conditioning will be postponed and that HFO-1234yf will be used as coolant as temporary measure to comply with the MAC Directive.

An important assumption is the amount of HFC-134a in the air conditioning system of new cars. We have used the data from Schwartz [7], 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).

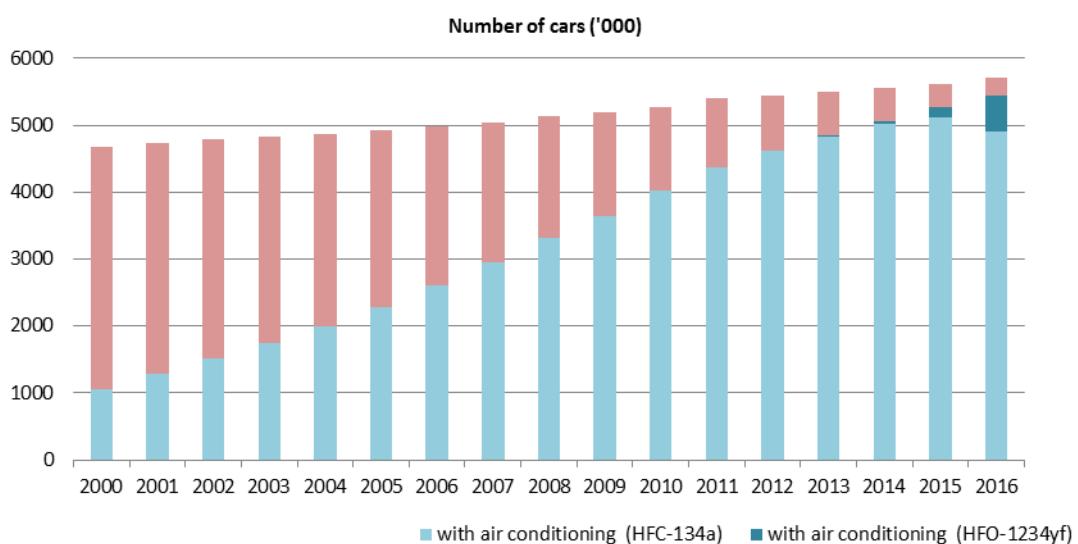


Figure 12. Stock of cars in Belgium with and without air conditioning

⁷ 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

⁸ 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.

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 [13]. 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 quick comparison revealed that the difference between the two is 5,6%).

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 2016, this is 69%. 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).

Table 12: Assumptions for mobile air conditioners and comparison with IPCC 2006 guidelines

	Car	Bus	Truck	Train	IPCC (2006)
Charge (kg)	0.5	11 – 12	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 13: Comparison of assumptions for car air conditioning between selected countries (in 2015).

indicator	BELGIUM	FRANCE	GERMANY	UK
Manufacturing EF (%)	2,8%	NR	0,25 - 0,63%	0,50%
Share HFO-1234yf (%)	24%	30%	NA	NR
Charge (g)	500	465	NR	NR
Lifetime (y)	11	12	15	15
Fugitive EF (%)	8,8%	Approx. 5%	10%	8%
Disposal EF (%)	91%	92%	57%	25%

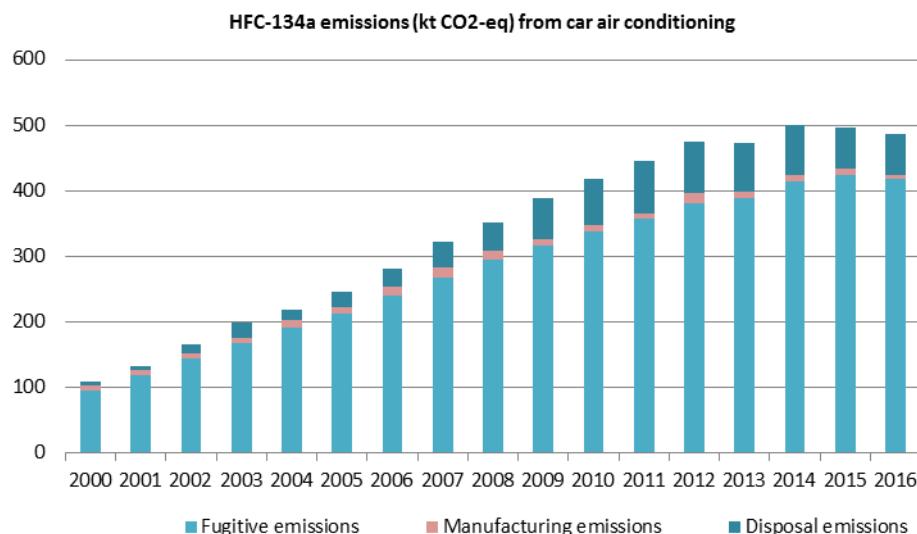


Figure 13: Emissions from car air conditioning (in kt CO2-eq)

6.1.5 Air conditioning in buses and coaches

Information on consumption and emissions of HFC-134a was received from all Belgian manufacturers.

The number of new registrations of buses and coaches was taken from the national statistics office [10] and divided assuming 29% buses and 71% coaches. In 2010, we have contacted the FPS Economy for more detailed and disaggregated information on the fleet of buses and coaches. They could provide us with information for recent years for buses and coaches separately. However, a significant part (around 40%) of the registered vehicles was classified in a third category 'unknown'. The vehicles that were identified as either bus or coach again corresponded with our assumption of 29% buses and 71% coaches.

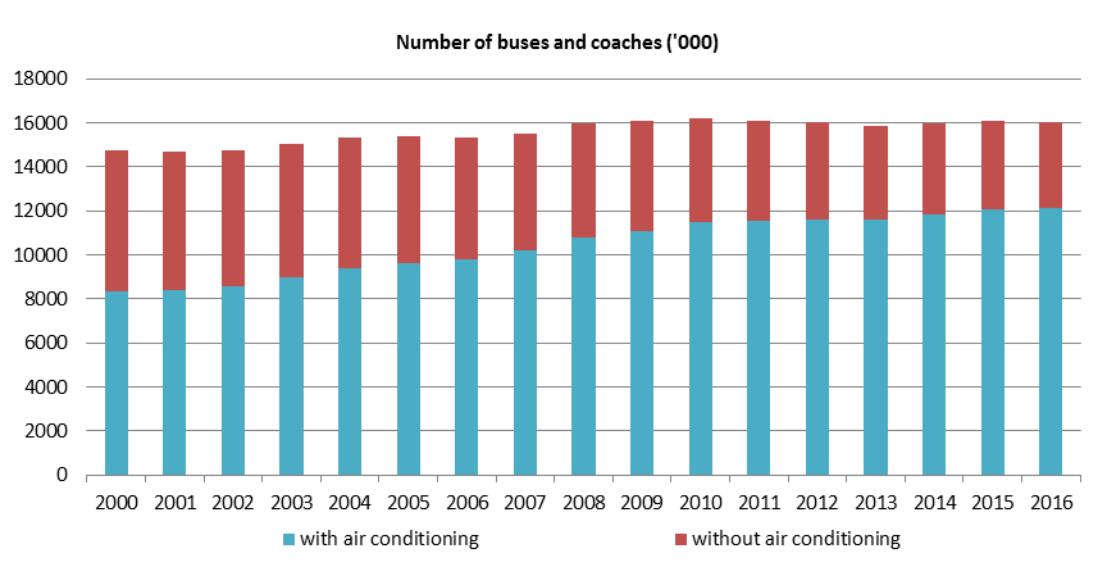


Figure 14. Stock of buses and coaches in Belgium with and without air conditioning

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

We use a model approach to estimate the number of buses and coaches in the entire fleet with air conditioning. In 2015, 75% of buses and coaches had air conditioning. The total fleet of buses and coaches for 2016 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 every 4 years.

The number of buses and coaches that are end-of-life in 2016 equals the number of new registrations in year x-17 (assuming average lifetime of 17 years). 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 14: Comparison of assumptions for bus air conditioning between selected countries (in 2015).

Indicator	Belgium	France	Germany	UK
Manufacturing EF (%)	2,40%	NR	0,42 -0,45%	0,50%
Charge (kg)	11 kg	10 kg	NR	4 kg
Share R134a (%)	100%	100%	NR	NR
Lifetime (y)	17	20	15	10
Fugitive EF (%)	15%	12%	15%	9%
Disposal EF (%)	30%	91%	62%	20%

NR = Not reported in NIR

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. 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 [7]). In comparison to the previous inventory, road tractors were also included (added to the high weight category). For each weight category, different assumptions are taken with respect to percentages of new vehicles equipped with air conditioning.

Table 15: Comparison of assumptions for truck air conditioning between selected countries (in 2015)

indicator	BELGIUM	FRANCE	GERMANY	UK
Manufacturing EF (%)	1%	NR	5 g	0,50%
Charge (kg)	0,85 - 1,08 kg	0,73 kg	NR	4 kg
Share R134a (%)	88%	90%	NR	NR
Lifetime (y)	12	12	15	10
Fugitive EF (%)	8 - 11%	35 g/year	15%	9%
Disposal EF (%)	30%	NR	60%	20%

NR = Not reported in NIR

Fugitive emission factors are taken from [14], 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 (24% HFO-1234yf in 2015).

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.

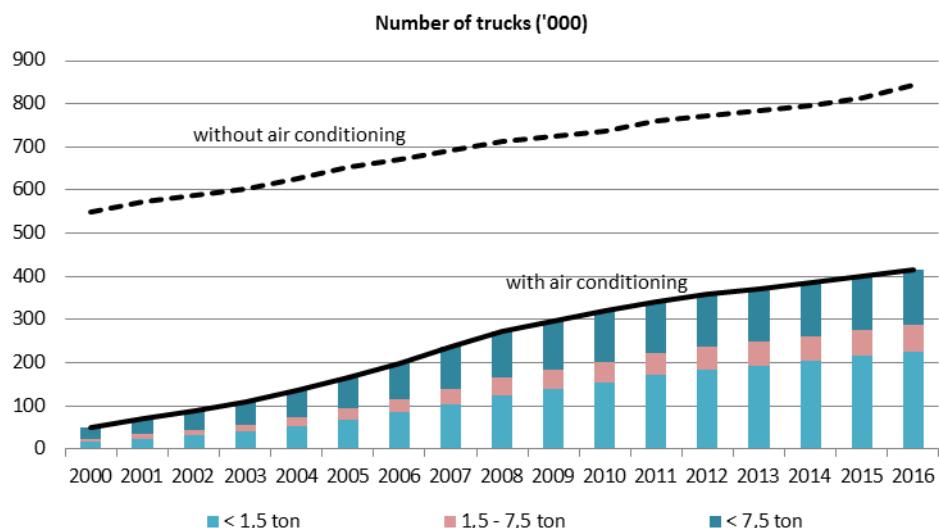


Figure 15. Stock of trucks in Belgium with and without air conditioning

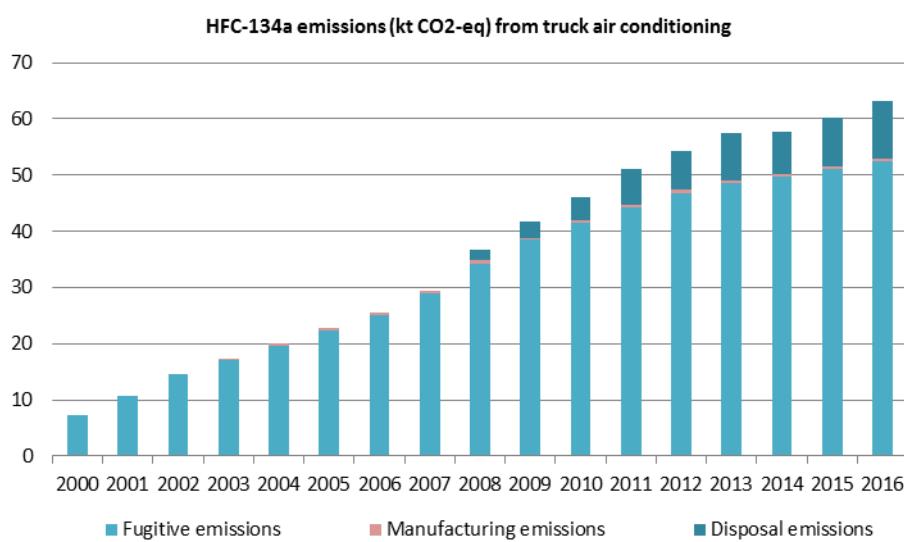


Figure 16: Emissions from truck air conditioning (in kt CO2-eq)

6.1.7 Air conditioning in rail transport

There are very few trams and metros with air conditioning, 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 2016. The vehicle fleet with air conditioning is slowly increasing.

The average quantity of HFC-134a per vehicle, by type, was received 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 5,2% (HFC-134a) and 8,2% (HFC-407c) was used (data from the NMBS/SNCB).

The disposal emissions are estimated at 20%, but it is expected that the first trains with air conditioning will be taken out of service only in 2023.

Table 16: Comparison of assumptions for train air conditioning between selected countries (in 2015)

Indicator	Belgium	France	Germany	UK
Manufacturing EF (%)		NR	0,50%	NR
Charge	12 - 14,5 kg	10,3 kg	NR	NR
Share R134a	91%	75%	NR	NR
Share R407c	9%	25%	NR	NR
Lifetime	40	15	25	NR
Fugitive EF (%)	5%-8%	5%	6%	NR
Disposal EF (%)	20%	35%	NO	NR

NR = not reported in NIR

6.1.8 Refrigerated transport

This section concerns refrigerated trucks and trailers⁹.

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

Data on the fleet and new registrations of refrigerated trucks and trailers for 2016 are obtained from the FPS Mobility for different weight categories. The raw 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. The fleet of refrigerated trucks is

⁹ 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.

modelled based on the number of new registered trucks (starting in 1993) and assuming an average life time of 12 years. Information on the substances and average quantities of F-gases in each weight category is based on assumptions taken from [7] 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 (including retrofitting of R404a installation to R452a). From 2018 it is expected that all new installations will use R452a.

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.

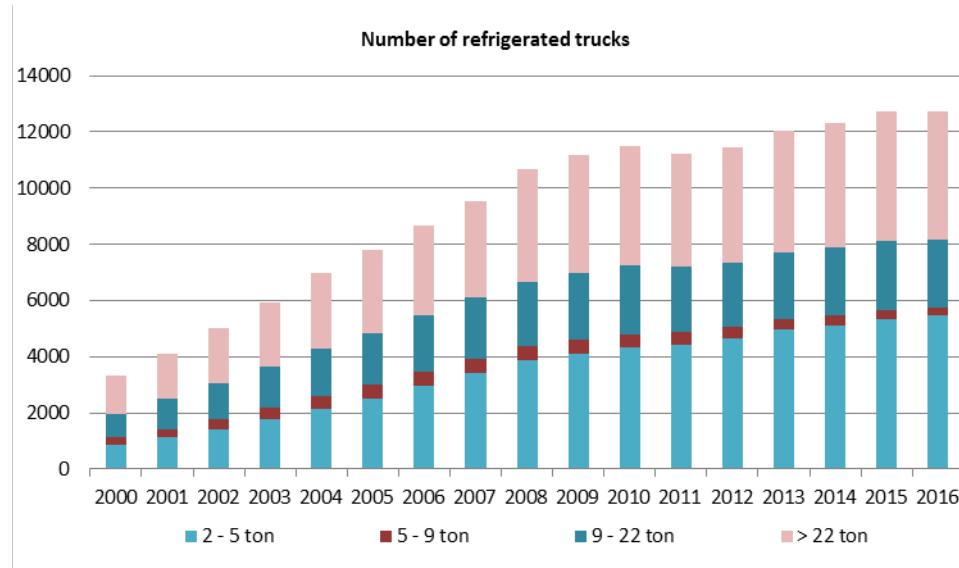


Figure 17. Stock of refrigerated trucks in Belgium.

Table 17: Comparison of assumptions for refrigerated transport between selected countries (in 2015)

Indicator	Belgium	France	Germany	UK
Manufacturing EF (%)	NO	NR	5 g	0,20%
Lifetime	12 years	10 years	NR	7 years
Fugitive EF (%)	15%	11%-20%	15%-30%	10%
Disposal EF (%)	30%	NR	NR	13%
Charge	1,5 kg - 9 kg	1,6 - 6,3 kg	NR	3,6 kg
2-5t: Share R134a	50%	10%	50%	NR
2-5 t: Share R404a	50%	90%	50%	NR
5-9t: Share R134a	50%	10%	50%	NR
5-9t: Share R404a	50%	90%	50%	NR
9-22t: Share R134a	10%	10%	NR	NR
9-22t: Share R404a	80%	90%	78-95%	NR
9-22t: Share R410a	10%	0%	NR	NR

>22t: Share R134a	5%	10%	NR	NR
>22t: Share R404a	85%	90%	78-95%	NR
>22t: Share R410a	10%	0%	NR	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 "Galden" (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 7 t or 7,1 kt CO₂-eq. in 2014, which is not very significant.

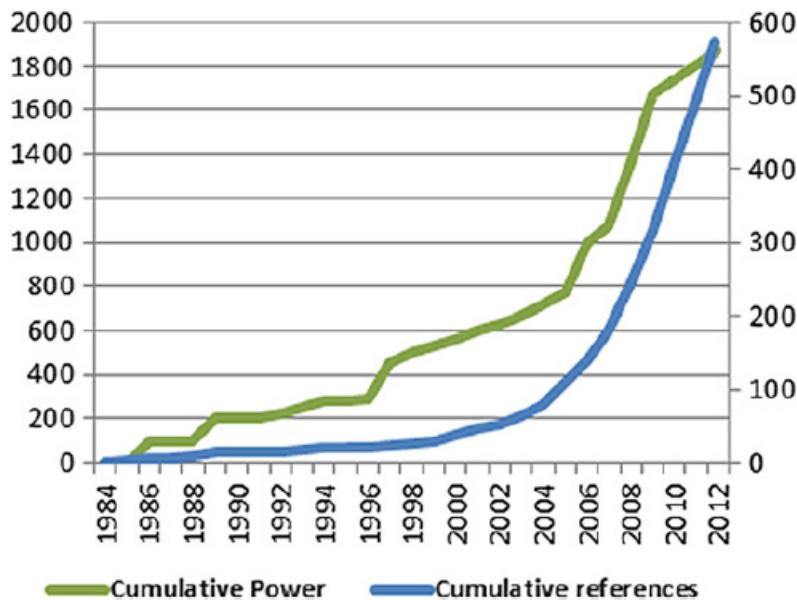


Figure 18. Market evolution (green, left) and share of each application in terms of number of units (blue, right) [15].

6.1.10 Tractors

Air conditioning in tractors or agricultural vehicles are not often included separately in inventories of other countries¹⁰. Germany and Austria included information on emissions from agricultural vehicles in their NIR. Based on this information and data on registered tractors in Belgium a first 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 2016 reached a level of almost 11 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.

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).

¹⁰ Not included separately for instance in France, the UK and Sweden.

The fugitive emission factor was estimated to be 5% per year in recent years [16], 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 available on how long these reefers remain in Belgium, before being transported to other countries. If we assume that each TEU corresponds with a reefer being only one day within Belgium – total annual emissions from reefers would be 1,3 kt CO₂-eq. per year. In the case this is 10 days, 13 kt CO₂-eq per year. Unfortunately, no statistics are available on the average amount of time reefers are placed on the docks. The emissions resulting from the assumption of 10 days are in line with the German approach of allocating a share of global emissions to Belgium based on global trade.

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 [17]). 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 [18]. 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 1,15%.

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 65% in 2015)¹¹. 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 3,6 kt CO₂-eq. in 2016. 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 [19].

¹¹ 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.

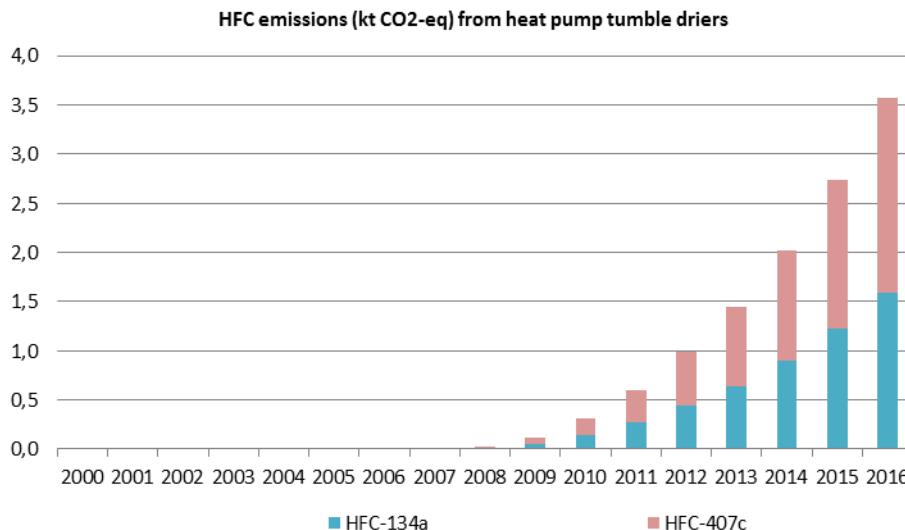


Figure 19. Emissions from heat pump tumble driers (in kt CO₂-eq)

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 20 below shows that HCFCs have practically disappeared between 2000 and 2004, because of European Regulation 2037/2000, which has been compensated by a much more limited increase in HFCs. The latter have decreased between 2010 and 2013; since then there is a small increase, in particular for PU 2-component spray foam. Besides, HFO-1234ze has been used since 2013.

HFCs have also partly been replaced by hydrocarbons, but they continue to be used for applications requiring special fire protection conditions.

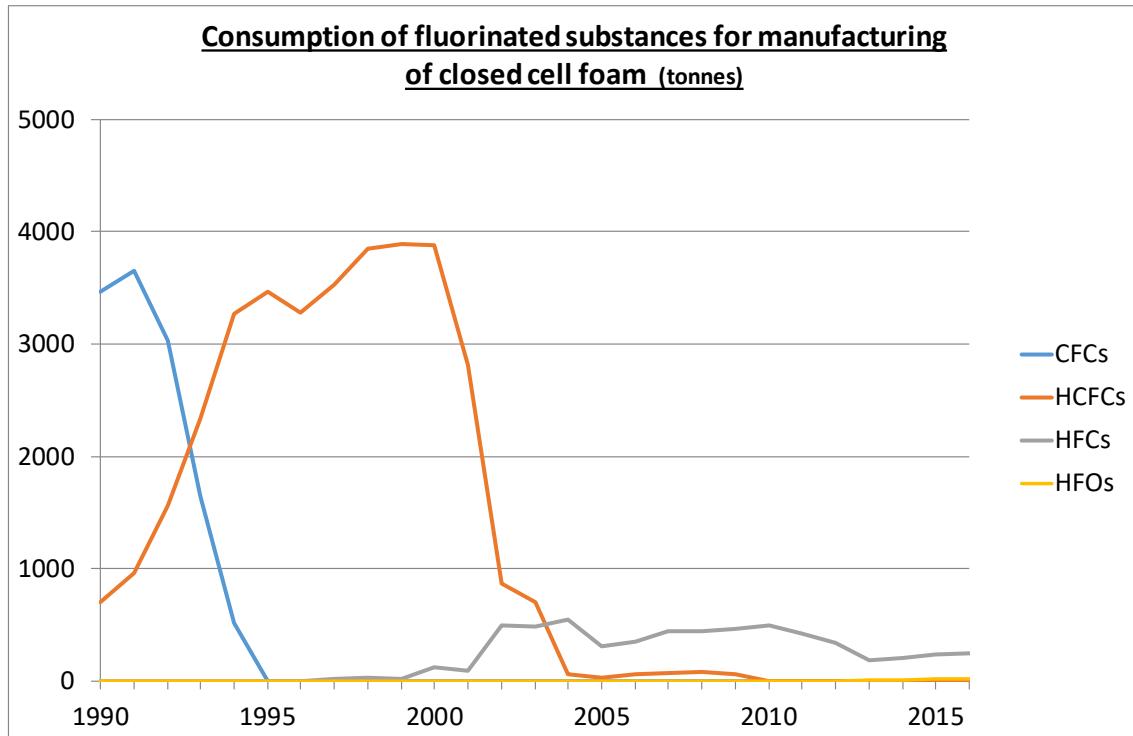


Figure 20: Consumption of F-gases for foam manufacturing (t)

The evolution of emissions in terms of CO₂ equivalent is shown on Figure 21, where one can notice the impact of the regular decline of existing stocks of CFCs and HCFCs, of which the impact is still dominant.

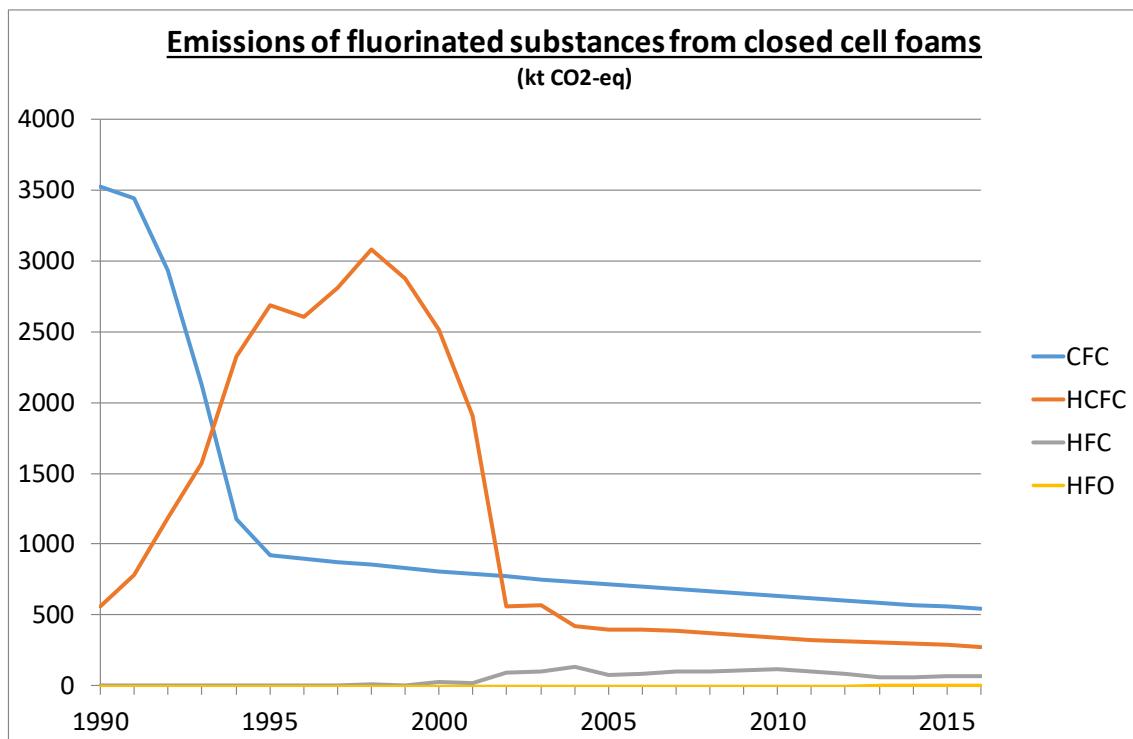


Figure 21: Emissions of F-gases from foams (kt CO₂-eq)

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 [20].

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 [20]. 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.

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 2009-2013 were obtained from GSK through LNE [21]. The figures for 2014 and 2015 were obtained by applying to those of 2013 the population growth.

Figure 22 below shows the development since 1995. Overall, after a strong evolution between 2000 and 2004, a lesser evolution up to 2009, and only a small increase in the latest years.

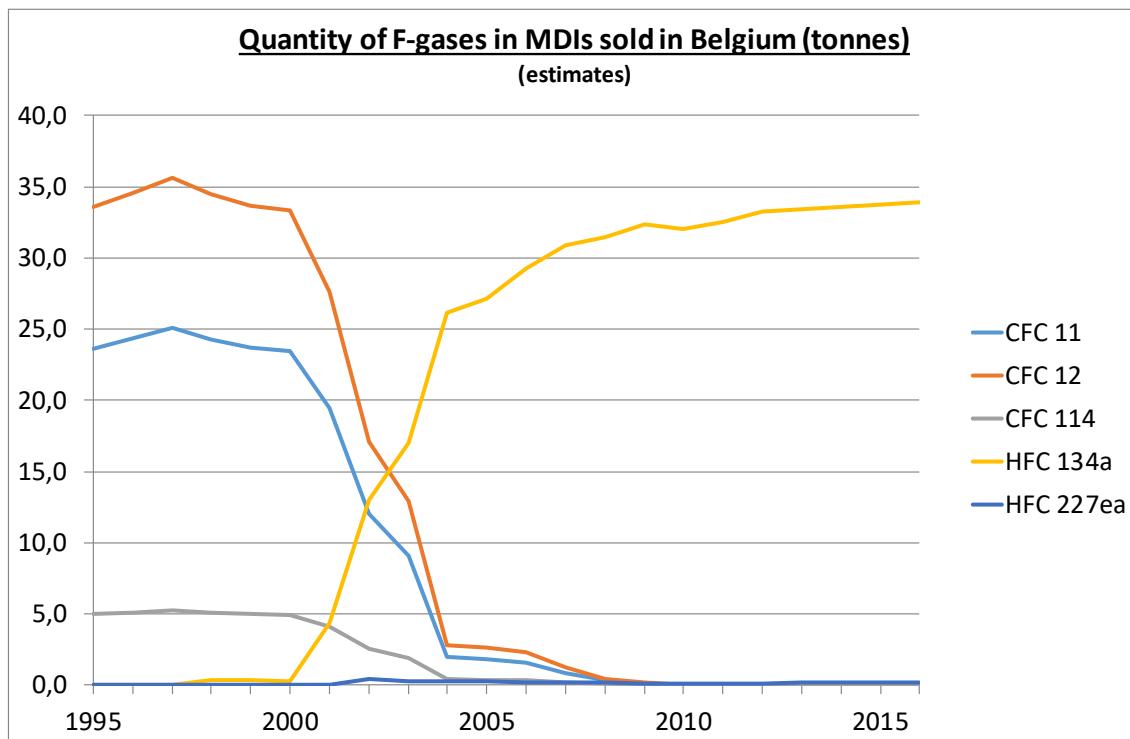


Figure 22: Number of MDI doses sold in Belgium (million)

The emissions, shown on Figure 23, 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.

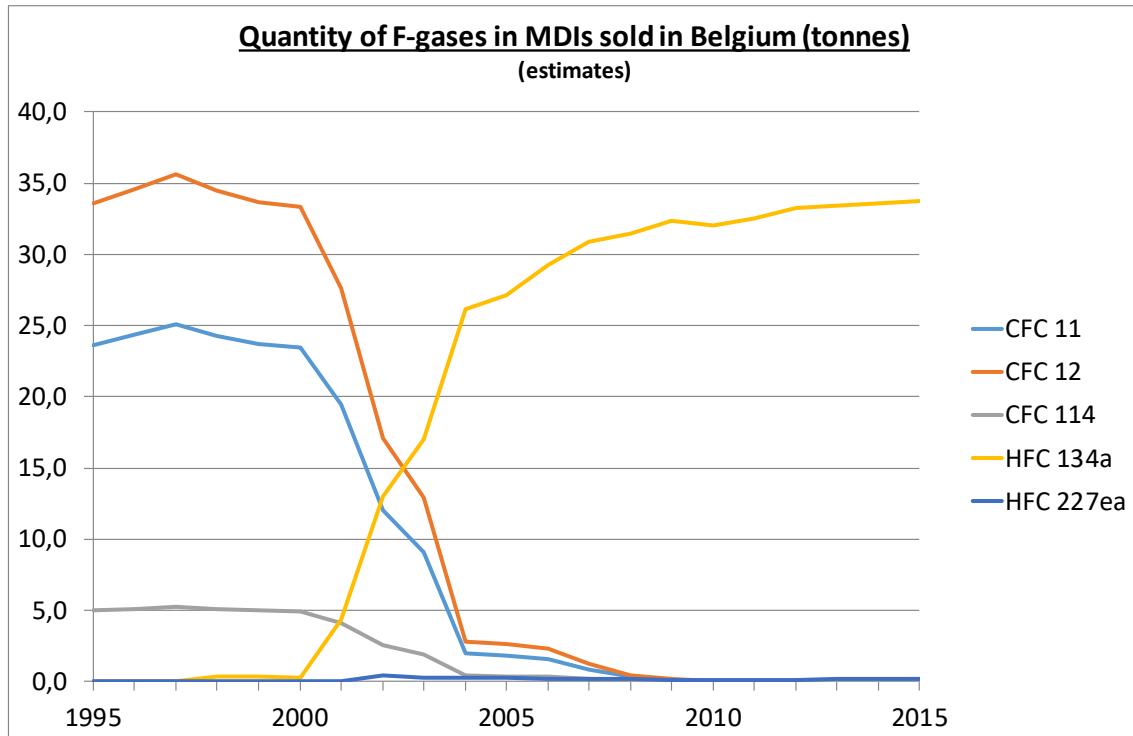


Figure 23: Quantity of F-gases in MDIs sold in Belgium (t)

In terms of greenhouse gas emissions, the evolution is shown on Figure 24. In the latest years emissions have reached a level of about 50 kt CO₂-eq.

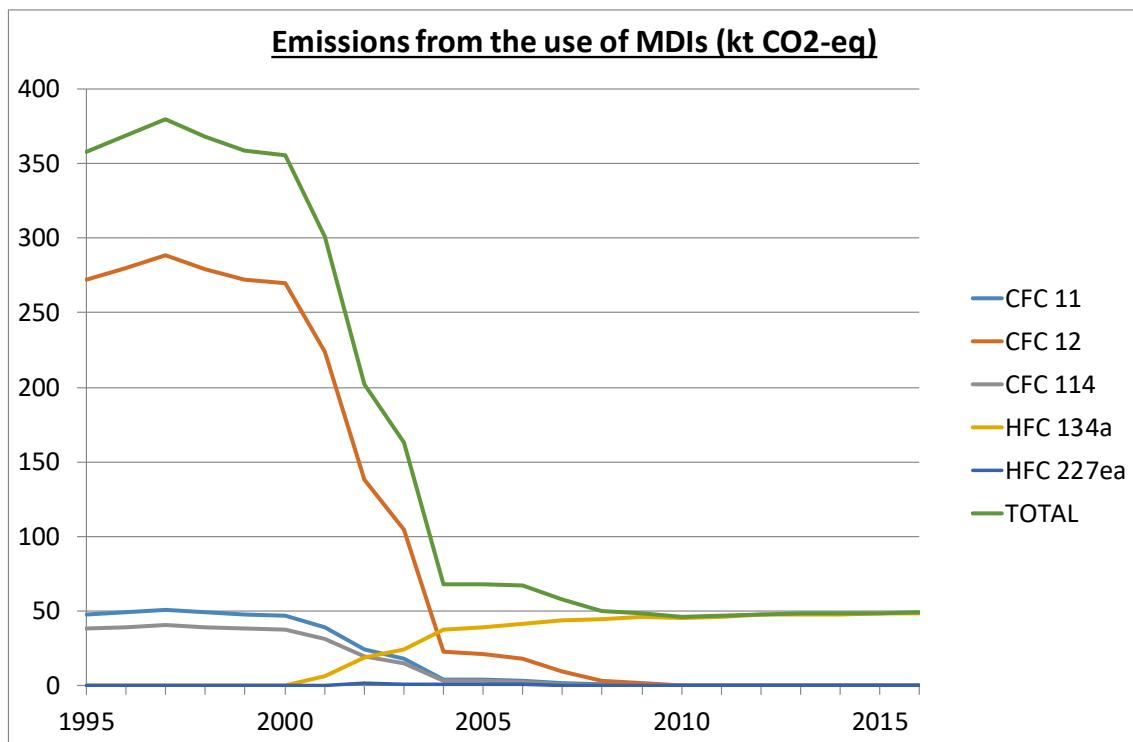


Figure 24: Emissions from the use of MDIs (kt CO₂-eq)

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 IMJVs¹² for 2016, which was split between HFC-134a and HFC-152a.

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 [7], 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.

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 2015. These per capita emissions have changed in the most recent inventory available and declined from 3,01 g/person in 2006 to 1,87 g/person in 2014 and 2,42 g/person in 2015. For 2016, the same emission factor as for 2015 is assumed.

¹² IMVJ: Integraal Milieu Jaarverslag.

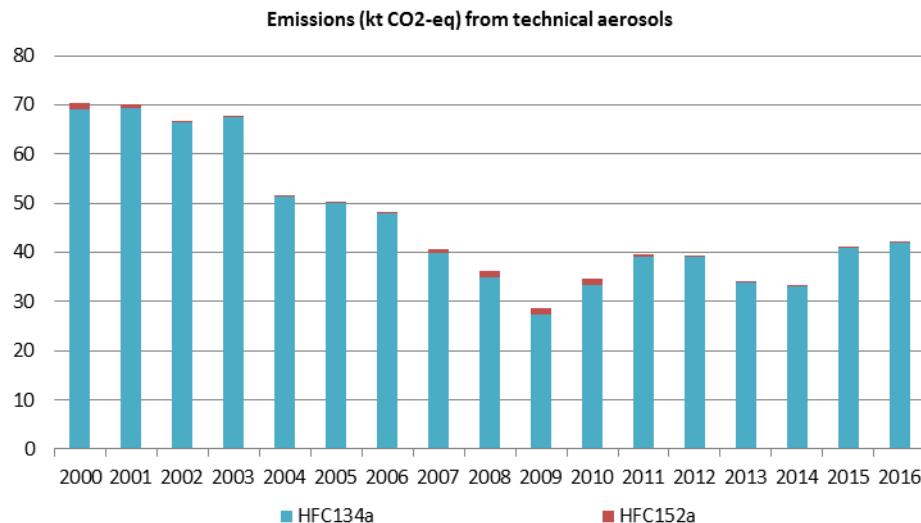


Figure 25: Emissions from the use of technical aerosols (kt CO₂-eq.)

6.5 Fire extinguishing

6.5.1 Fixed fire extinguisher installations

A questionnaire has been sent to five 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 (for 2015, two of them reported to have recovered HFC-125 and HFC-227ea from 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.

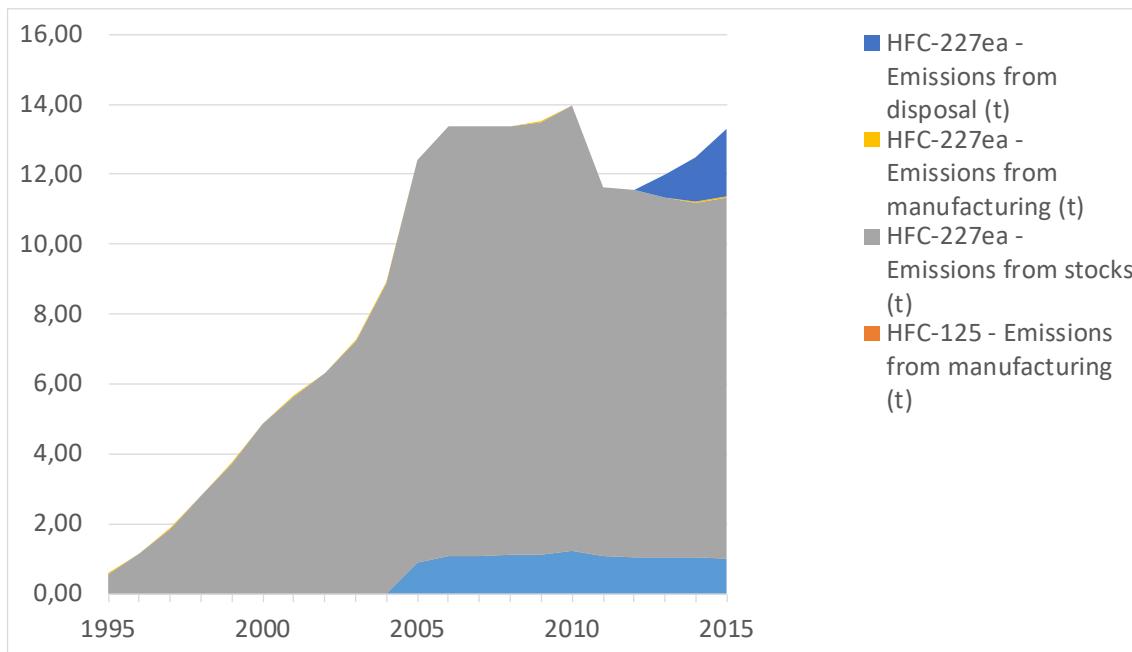


Figure 26: CRF gas emissions from fire extinguishers (kt CO₂-eq.)

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 2016. Photovoltex 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.

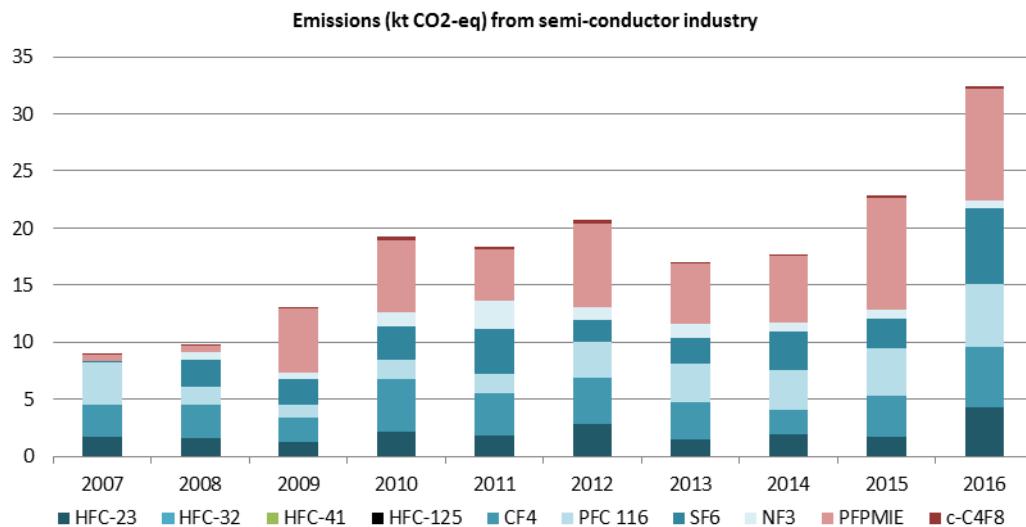


Figure 27: Emissions from semiconductor industry (in kt CO2-eq)

6.8 Methylbromide

The emissions of methylbromide are presented on Figure 28.

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 28.

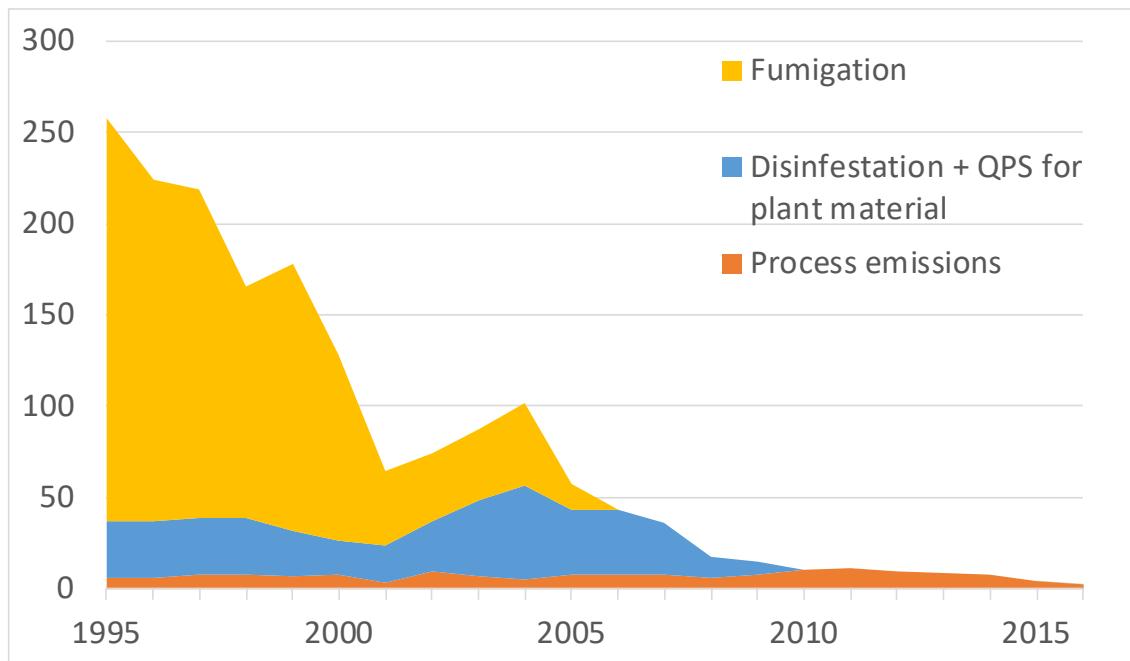


Figure 28: Emissions of methyl bromide (t)

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 • (1 – Recovery Factor)

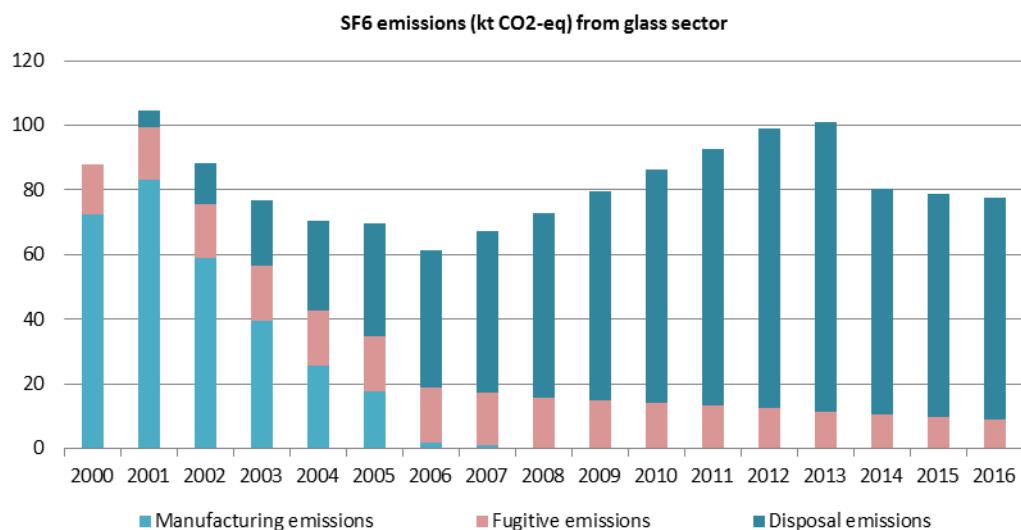


Figure 29. SF6 emissions from double glass in Belgium (in kt CO2-eq).

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 2016 of SF6 from disposal were 3,01 t.

6.9.2 Electricity sector

We received data from ELIA and FEBEG. For 2016, data on SF6 use in switchgears installed in wind turbines was included.

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 2016. FEBEG reported the stock of SF6 in all large power stations in 2016 and the average quantity in switch gear in wind turbines. We have included these quantities also in the stock data, using data on the number of wind turbines installed in Belgium (onshore and offshore).



Figure 30. SF6 bank (in t) in switchgear in Belgium at the end of the year.

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 2016¹³.

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 life time 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.

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

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

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 SF ₆ 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 (e.g. the Netherlands and Finland have not included it). 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

An overview of the emissions of SF6, CF4, C2F6, C3F8, C4F10, C5F12, C6F14 and the other non-IPCC gases (fugitive and non-fugitive) has been obtained for an electrochemical plant.

A full time series is given for all IPCC greenhouse gases. However, the electrochemical plant also provides information on a number of non-IPCC F- gases. For the period 1990-2003, information is available on individual substances. In the period 2004-2010, this company provided only aggregated data (expressed in t and kt CO₂ equivalent) of an unspecified mix. The GWP value of this mix was provided and fluctuates from year to year. Production data are based on the total quantity of non-IPCC gases (in t) which were disaggregated over individual substances by the company. The emission factors for each of these substances is however not the same, so this approach is only a rough approximation. From 2011 to 2015, emissions for the most common non-IPCC gases are again reported.

In 2014, the company recalculated emission factors based on laboratory experiments. These tests showed that HFC emissions could have been underestimated. The evaluation of whether using emission factors from the laboratory results (instead of current emission factors) would result in a more accurate estimate of the emissions for the entire time series is still ongoing. Because there is still uncertainty regarding the new emission factors, emissions have been

estimated based on the previous methodology also for this year's emission inventory (up to 2016). This means that the time series is consistent.

In 2016, emissions of IPCC F-gases are considerably higher than in 2015. This increase is due to temporary problems with the effectiveness of the incinerator that is installed since 1997.

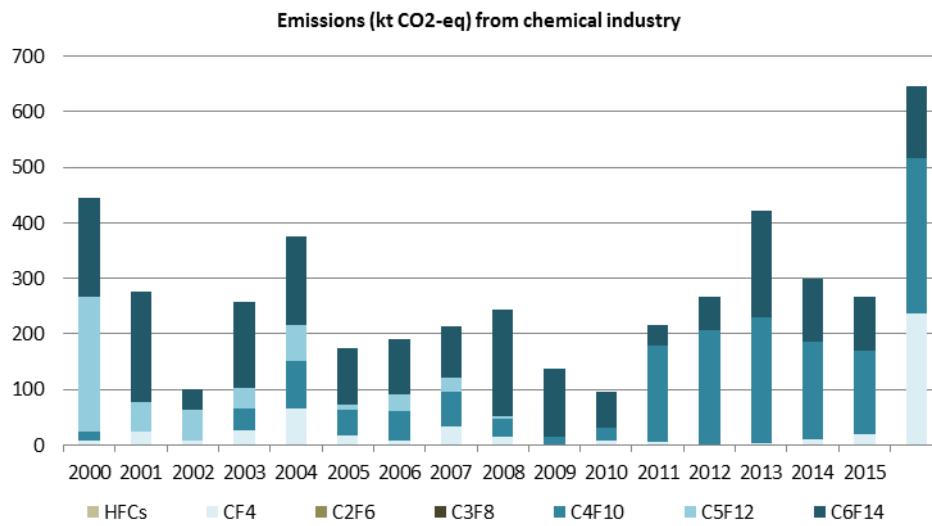


Figure 31: Emissions from chemical industry (in kt CO₂-eq)

This company only places relatively small quantities of F-gases on the Belgian market. In 2015, it did not place any.

7 OVERALL RESULTS

The results are presented below for the base year for F-gases in the Kyoto protocol (1995) and for the most recent year (2016), 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.

7.1 Emissions in tonnes in 2016

BELGIUM 2016 (tonnes)	Refrigeration & air conditioning	Foams	Fire protection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
ODS	17,6	264,2	2,5					2,1	286,4
CFC	0,0	105,6							105,7
CFC-11	0,0	51,0							51,0
CFC-12	0,0	54,6							54,7
CFC-115	0,0								0,0
HCFC	17,5	158,6							176,1
HCFC-22	17,2								17,2
HCFC-124	0,2								0,2
HCFC-141b		9,9							9,9
HCFC-142b	0,1	148,7							148,8
Halons			2,5						2,5
Halon 1211			0,2						0,2
Halon 1301			2,3						2,3
Other ODS							2,1	2,1	
CH3Br							2,1	2,1	2,1
CRF	1 206,4	198,7	4,0	66,1		77,5	1,8	3,9	1 558,3
HFC	1 206,2	198,7	4,0	66,1			0,3		1 475,2
HFC-125	263,5		0,3				0,0		263,7
HFC-134a	671,6	43,1		63,3					778,0
HFC-143a	177,3								177,3
HFC-152a	0,0	144,0		2,6					146,6
HFC-227ea		1,3	3,7	0,2					5,2
HFC-23							0,3		0,3
HFC-245fa		0,7							0,7
HFC-32	93,8						0,0		93,8
HFC-365mfc		9,5							9,5
HFC-41							0,0		0,0
PFC	0,2					77,5	1,2		78,8
C2F6 (PFC-116)							0,5		0,5
C3F8 (PFC-218)	0,2								0,2
C4F10					31,6				31,6
C5F12					0,0				0,0
C6F14					14,1				14,1
c-C4F8						0,0			0,0
CF4					31,8	0,7			32,5
SF6							0,3	3,9	4,2
NF3							0,0		0,0
Other	0,9	17,7				74,0	1,0		93,6
HFO	0,9	17,7							18,6
R-1234yf	0,9								0,9
R-1234ze	0,1	17,7							17,7
Other						74,0	1,0		75,0
PFPMIE							1,0		1,0
Unspecified mix						74,0			74,0
General total	1 224,9	480,6	6,5	66,1	0,0	151,5	2,8	6,0	1 938,4

FLANDERS 2016 (tonnes)	Refrigeration & air conditioning	Foams	Fire protection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
ODS	10,1	151,9	1,4					2,1	165,6
CFC	0,0	60,7							60,7
CFC-11	0,0	29,3							29,3
CFC-12	0,0	31,4							31,4
CFC-115	0,0								0,0
HCFC	10,1	91,2							101,3
HCFC-22	9,9								9,9
HCFC-124	0,1								0,1
HCFC-141b		5,7							5,7
HCFC-142b	0,1	85,5							85,5
Halons			1,4						1,4
Halon 1211			0,1						0,1
Halon 1301			1,3						1,3
Other ODS								2,1	2,1
CH3Br								2,1	2,1
CRF	702,9	182,1	2,3	40,0		77,5	1,8	2,2	1 008,7
HFC	702,7	182,1	2,3	40,0			0,3		927,4
HFC-125	152,3		0,6				0,0		152,9
HFC-134a	393,7	29,9		37,7					461,3
HFC-143a	102,6								102,6
HFC-152a	0,0	141,4		2,2					143,6
HFC-227ea		1,3	1,7	0,1					3,1
HFC-23							0,3		0,3
HFC-245fa			0,5						0,5
HFC-32	54,2						0,0		54,2
HFC-365mfc		9,0							9,0
HFC-41							0,0		0,0
PFC	0,1					77,5	1,2		78,8
C2F6 (PFC-116)							0,5		0,5
C3F8 (PFC-218)	0,1								0,1
C4F10					31,6				31,6
C5F12					0,0				0,0
C6F14					14,1				14,1
c-C4F8							0,0		0,0
CF4					31,8	0,7			32,5
SF6							0,3	2,2	2,5
NF3							0,0		0,0
Other	0,5	17,4				74,0	1,0		93,0
HFO	0,5	17,4							17,9
R-1234yf	0,5								0,5
R-1234ze	0,0	17,4							17,4
Other						74,0	1,0		75,0
PFPMIE							1,0		1,0
Unspecified mix						74,0			74,0
General total	713,5	351,4	3,7	40,0	0,0	151,5	2,8	4,4	1 267,3

WALLONIA 2016 (tonnes)	Refrigeration & air conditioning	Foams	Fire protection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
ODS	5,6	84,5	0,8						90,9
CFC	0,0	33,8							33,8
CFC-11	0,0	16,3							16,3
CFC-12	0,0	17,5							17,5
CFC-115	0,0								0,0
HCFC	5,6	50,7							56,3
HCFC-22	5,5								5,5
HCFC-124	0,1								0,1
HCFC-141b		3,2							3,2
HCFC-142b	0,0	47,5							47,6
Halons			0,8						0,8
Halon 1211			0,0						0,0
Halon 1301			0,8						0,8
CRF	379,3	12,5	1,3	19,6				1,2	413,9
HFC	379,2	12,5	1,3	19,6					412,6
HFC-125	83,6		0,1						83,7
HFC-134a	209,7	9,9		19,3					238,9
HFC-143a	56,1								56,1
HFC-152a	0,0	1,9		0,3					2,3
HFC-227ea		0,0	1,2	0,1					1,3
HFC-245fa		0,2							0,2
HFC-32	29,8								29,8
HFC-365mfc		0,4							0,4
PFC	0,1								0,1
C3F8 (PFC-218)	0,1								0,1
SF6								1,2	1,2
Other	0,3	0,2							0,5
HFO	0,3	0,2							0,5
R-1234yf	0,3								0,3
R-1234ze	0,0	0,2							0,2
General total	385,2	97,1	2,1	19,6	0,0	0,0	0,0	1,2	505,2

BRUSSELS 2016 (tonnes)	Refrigeration & air conditioning	Foams	Fire protection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
ODS	1,9	27,9	0,3	0,0					30,0
CFC	0,0	11,1		0,0					11,1
CFC-11	0,0	5,4		0,0					5,4
CFC-12	0,0	5,8		0,0					5,8
CFC-115	0,0								0,0
HCFC	1,8	16,7							18,6
HCFC-22	1,8								1,8
HCFC-124	0,0								0,0
HCFC-141b		1,0							1,0
HCFC-142b	0,0	15,7							15,7
Halons			0,3						0,3
Halon 1211			0,0						0,0
Halon 1301			0,2						0,2
CRF	124,3	4,1	0,4	6,5				0,4	135,7
HFC	124,2	4,1	0,4	6,5					135,2
HFC-125	27,6		0,0						27,6
HFC-134a	68,3	3,3		6,3					77,9
HFC-143a	18,6								18,6
HFC-152a	0,0	0,6		0,1					0,7
HFC-227ea		0,0	0,4	0,0					0,4
HFC-245fa		0,0							0,0
HFC-32	9,8								9,8
HFC-365mfc		0,1							0,1
PFC	0,0								0,0
C3F8 (PFC-218)	0,0								0,0
SF6								0,4	0,4
Other	0,1	0,1							0,2
HFO	0,1	0,1							0,2
R-1234yf	0,1								0,1
R-1234ze	0,0	0,1							0,1
General total	126,2	32,0	0,7	6,5	0,0	0,0	0,0	0,4	165,8

7.2 Emissions in tonnes in 1995

BELGIUM 1995 (tonnes)	Refrigeration & air conditioning	Foams	Fire protection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
ODS	1 588,6	2 162,3	12,5	69,4	50,0			287,1	4 169,9
CFC	705,2	443,1		69,4					1 217,7
CFC-11	66,4	343,9		27,2					437,5
CFC-12	557,7	99,2		37,2					694,1
CFC-114				5,0					5,0
CFC-115	81,2								81,2
HCFC	883,4	1 719,2			50,0				2 652,6
HCFC-22	883,4	1 014,0			50,0				1 897,4
HCFC-141b		219,5			50,0				269,5
HCFC-142b		485,7							485,7
Halons			12,5						12,5
Halon 1211			1,7						1,7
Halon 1301			10,8						10,8
Other ODS							287,1	287,1	
CCl4							29,2	29,2	
CH3Br							257,9	257,9	
CRF	67,0	250,0	0,2	29,3		397,7		5,9	750,0
HFC	67,0	250,0	0,2	29,3					346,4
HFC-125	1,3								1,3
HFC-134a	64,1	249,5		29,0					342,5
HFC-143a	1,5								1,5
HFC-152a		0,5		0,3					0,8
HFC-227ea			0,2						0,2
HFC-245fa		0,0							0,0
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		5,9	93,8
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	1 655,6	2 412,3	12,6	98,7	50,0	655,9		293,0	5 178,1

FLANDERS 1995 (tonnes)	Refrigeration & air conditioning	Foams	Fire protection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
ODS	929,2	1 098,6	7,2	43,2	29,0			276,5	2 383,6
CFC	408,9	259,0		43,2					711,2
CFC-11	38,4	201,6		17,3					257,3
CFC-12	323,5	57,4		23,0					404,0
CFC-114				2,9					2,9
CFC-115	47,0								47,0
HCFC	520,2	839,5			29,0				1 388,7
HCFC-22	520,2	395,0							915,2
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	40,1	149,1	0,1	17,0		397,7		3,4	607,4
HFC	40,1	149,1	0,1	17,0					206,2
HFC-125	0,8								0,8
HFC-134a	38,4	148,8		16,8					203,9
HFC-143a	0,9								0,9
HFC-152a		0,3		0,2					0,5
HFC-227ea			0,1						0,1
HFC-245fa		0,0							0,0
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	969,3	1 247,7	7,3	60,2	29,0	655,9	0,0	279,9	3 249,1

WALLONIA 1995 (tonnes)	Refrigeration & air conditioning	Foams	Fire protection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
ODS	512,2	1 016,5	4,1	20,3	16,4			10,3	1 579,7
CFC	230,1	143,3		20,3					393,7
CFC-11	21,7	110,8		7,7					140,3
CFC-12	181,9	32,4		11,0					225,3
CFC-114				1,6					1,6
CFC-115	26,5								26,5
HCFC	282,1	873,2			16,4				1 171,7
HCFC-22	282,1	619,0							901,1
HCFC-141b		2,1			16,4				18,5
HCFC-142b		252,1							252,1
Halons			4,1						4,1
Halon 1211			0,5						0,5
Halon 1301			3,5						3,5
Other ODS							10,3	10,3	
CCl4							1,0	1,0	
CH3Br							9,3	9,3	
CRF	20,4	78,9	0,1	9,6			2,2	111,2	
HFC	20,4	78,9	0,1	9,6					109,0
HFC-125	0,4								0,4
HFC-134a	19,6	78,8		9,5					107,8
HFC-143a	0,5								0,5
HFC-152a		0,1		0,1					0,2
HFC-227ea			0,1						0,1
HFC-245fa		0,0							0,0
SF6							2,2	2,2	
General total	532,7	1 095,3	4,1	29,9	16,4	0,0	0,0	12,5	1 690,9

BRUSSELS 1995 (tonnes)	Refrigeration & air conditioning	Foams	Fire protection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
ODS	147,2	47,3	1,2	5,8	4,7			0,4	206,6
CFC	66,2	40,8		5,8					112,8
CFC-11	6,2	31,5		2,2					39,9
CFC-12	52,3	9,3		3,2					64,8
CFC-114				0,5					0,5
CFC-115	7,6								7,6
HCFC	81,0	6,5			4,7				92,2
HCFC-22	81,0								81,0
HCFC-141b		0,2			4,7				4,9
HCFC-142b		6,3							6,3
Halons			1,2						1,2
Halon 1211			0,2						0,2
Halon 1301			1,0						1,0
Other ODS							0,4	0,4	
CCl4							0,1	0,1	
CH3Br							0,3	0,3	
CRF	6,4	22,0	0,0	2,8			0,3	31,5	
HFC	6,4	22,0	0,0	2,8					31,2
HFC-125	0,1								0,1
HFC-134a	6,2	21,9		2,7					30,8
HFC-143a	0,1								0,1
HFC-152a		0,0		0,0					0,1
HFC-227ea			0,0						0,0
HFC-245fa		0,0							0,0
SF6							0,3	0,3	
General total	153,7	69,2	1,2	8,6	4,7	0,0	0,0	0,6	238,1

7.3 Emissions in kt CO₂-eq in 2016

BELGIUM 2016 (kt CO ₂ -eq)	Refrigeration & air conditioning	Foams	Fire pro- tection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
ODS	29,2	822,6	-92,3					-2,7	756,7
CFC	0,3	545,5							545,8
CFC-11	0,0	102,9							103,0
CFC-12	0,3	442,6							442,9
CFC-115	0,0								0,0
HCFC	28,9	277,0							305,9
HCFC-22	28,7								28,7
HCFC-124	0,1								0,1
HCFC-141b		5,2							5,2
HCFC-142b	0,2	271,8							272,0
Halons			-92,3						-92,3
Halon 1211			-2,6						-2,6
Halon 1301			-89,7						-89,7
Other ODS								-2,7	-2,7
CH3Br								-2,7	-2,7
CRF	2 740,2	92,1	12,9	91,4		645,7	22,7	88,1	3 693,1
HFC	2 738,4	92,1	12,9	91,4			4,3		2 939,2
HFC-125	922,1		0,9				0,0		923,0
HFC-134a	960,4	61,7		90,5					1 112,6
HFC-143a	792,6								792,6
HFC-152a	0,0	17,9		0,3					18,2
HFC-227ea		4,3	12,0	0,6					16,9
HFC-23							4,3		4,3
HFC-245fa		0,7							0,7
HFC-32		63,3					0,0		63,3
HFC-365mfc			7,5						7,5
HFC-41							0,0		0,0
PFC	1,8					645,7	11,0		658,6
C2F6 (PFC-116)							5,5		5,5
C3F8 (PFC-218)	1,8								1,8
C4F10					279,8				279,8
C5F12					0,0				0,0
C6F14					131,0				131,0
c-C4F8							0,2		0,2
CF4					234,9		5,3		240,2
SF6							6,6	88,1	94,7
NF3							0,7		0,7
Other	0,0	0,1				673,0	9,8		682,9
HFO	0,0	0,1							0,1
R-1234yf	0,0								0,0
R-1234ze	0,0	0,1							0,1
Other						673,0	9,8		682,8
PFPMIE							9,8		9,8
Unspecified mix						673,0			673,0
General total	2 769,4	914,8	-79,5	91,4	0,0	1 318,7	32,5	85,4	5 132,7

FLANDERS 2016 (kt CO2-eq)	Refrigeration & air conditioning	Foams	Fire pro- tection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
ODS	16,8	472,9	-53,1					-2,7	433,9
CFC	0,2	313,6							313,8
CFC-11	0,0	59,2							59,2
CFC-12	0,2	254,4							254,6
CFC-115	0,0								0,0
HCFC	16,6	159,3							175,9
HCFC-22	16,5								16,5
HCFC-124	0,0								0,0
HCFC-141b		3,0							3,0
HCFC-142b	0,1	156,3							156,4
Halons			-53,1						-53,1
Halon 1211			-1,5						-1,5
Halon 1301			-51,6						-51,6
Other ODS								-2,7	-2,7
CH3Br								-2,7	-2,7
CRF	1 592,3	72,1	7,4	54,5		645,7	22,7	51,2	2 445,9
HFC	1 591,3	72,1	7,4	54,5			4,3		1 729,6
HFC-125	533,0		0,5				0,0		533,5
HFC-134a	562,9	42,8		53,9					659,7
HFC-143a	458,8								458,8
HFC-152a	0,0	17,5		0,3					17,8
HFC-227ea		4,1	6,9	0,3					11,3
HFC-23							4,3		4,3
HFC-245fa		0,5							0,5
HFC-32	36,6						0,0		36,6
HFC-365mfc			7,1						7,1
HFC-41							0,0		0,0
PFC	1,0					645,7	11,0		657,8
C2F6 (PFC-116)							5,5		5,5
C3F8 (PFC-218)	1,0								1,0
C4F10					279,8				279,8
C5F12					0,0				0,0
C6F14					131,0				131,0
c-C4F8							0,2		0,2
CF4					234,9		5,3		240,2
SF6							6,6	51,2	57,8
NF3							0,7		0,7
Other	0,0	0,1				673,0	9,8		682,9
HFO	0,0	0,1							0,1
R-1234yf	0,0								0,0
R-1234ze	0,0	0,1							0,1
Other						673,0	9,8		682,8
PFPMIE							9,8		9,8
Unspecified mix						673,0			673,0
General total	1 609,1	545,1	-45,7	54,5	0,0	1 318,7	32,5	48,5	3 562,7

WALLONIA 2016 (kt CO2-eq)	Refrigeration & air conditioning	Foams	Fire pro- tection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
ODS	9,3	263,0	-29,5						242,8
CFC	0,1	174,4							174,5
CFC-11	0,0	32,9							32,9
CFC-12	0,1	141,5							141,6
CFC-115	0,0								0,0
HCFC	9,2	88,6							97,8
HCFC-22	9,2								9,2
HCFC-124	0,0								0,0
HCFC-141b		1,7							1,7
HCFC-142b	0,1	86,9							87,0
Halons			-29,5						-29,5
Halon 1211			-0,8						-0,8
Halon 1301			-28,7						-28,7
CRF	864,0	15,0	4,1	27,8				27,7	938,6
HFC	863,4	15,0	4,1	27,8					910,3
HFC-125	292,5		0,3						292,8
HFC-134a	299,9	14,2		27,5					341,6
HFC-143a	250,9								250,9
HFC-152a	0,0	0,2		0,0					0,3
HFC-227ea		0,1	3,8	0,2					4,2
HFC-245fa		0,2							0,2
HFC-32		20,1							20,1
HFC-365mfc		0,3							0,3
PFC	0,6								0,6
C3F8 (PFC-218)	0,6								0,6
SF6								27,7	27,7
Other	0,0	0,0							0,0
HFO	0,0	0,0							0,0
R-1234yf	0,0								0,0
R-1234ze	0,0	0,0							0,0
General total	873,3	278,0	-25,4	27,8	0,0	0,0	0,0	27,7	1 181,4

BRUSSELS 2016 (kt CO2-eq)	Refrigeration & air conditioning	Foams	Fire pro- tection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
ODS	3,1	86,7	-9,7	0,0					80,1
CFC	0,0	57,5		0,0					57,5
CFC-11	0,0	10,9		0,0					10,9
CFC-12	0,0	46,7		0,0					46,7
CFC-115	0,0			0,0					0,0
HCFC	3,0	29,2		0,0					32,3
HCFC-22	3,0			0,0					3,0
HCFC-124	0,0			0,0					0,0
HCFC-141b		0,5		0,0					0,5
HCFC-142b	0,0	28,7		0,0					28,7
Halons			-9,7	0,0					-9,7
Halon 1211			-0,3	0,0					-0,3
Halon 1301			-9,5	0,0					-9,5
CRF	284,0	5,0	1,4	9,2				9,1	308,6
HFC	283,8	5,0	1,4	9,2					299,2
HFC-125	96,6		0,1	0,0					96,7
HFC-134a	97,6	4,7		9,1					111,4
HFC-143a	82,9			0,0					82,9
HFC-152a	0,0	0,1		0,0					0,1
HFC-227ea		0,0	1,3	0,1					1,4
HFC-245fa		0,0		0,0					0,0
HFC-32		6,6		0,0					6,6
HFC-365mfc		0,1		0,0					0,1
PFC	0,2			0,0					0,2
C3F8 (PFC-218)	0,2			0,0					0,2
SF6				0,0				9,1	9,1
Other	0,0	0,0		0,0					0,0
HFO	0,0	0,0		0,0					0,0
R-1234yf	0,0			0,0					0,0
R-1234ze	0,0	0,0		0,0					0,0
General total	287,1	91,7	-8,4	9,2	0,0	0,0	0,0	9,1	388,6

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	6 724,1	4 185,7	-441,1	394,4	26,1		0,0	-333,0	10 556,2
CFC	5 255,9	1 498,2		394,4			0,0		7 148,5
CFC-11	134,1	694,7		55,0			0,0		883,7
CFC-12	4 517,5	803,5		301,2					5 622,2
CFC-114				38,2					38,2
CFC-115	604,4								604,4
HCFC	1 468,2	2 687,5			26,1				4 181,8
HCFC-22	1 468,2	1 685,3							3 153,5
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	103,2	356,8	0,6	41,5		4 919,6		134,5	5 556,0
HFC	103,2	356,8	0,6	41,5					502,0
HFC-125	4,6								4,6
HFC-134a	91,7	356,7		41,4					489,8
HFC-143a	6,9								6,9
HFC-152a		0,1		0,0					0,1
HFC-227ea			0,6						0,6
HFC-245fa		0,0							0,0
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		134,5	2 139,7
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	6 827,3	4 542,5	-440,5	435,8	26,1	7 931,6	0,0	-198,5	19 124,2

FLANDERS 1995 (kt CO ₂ -eq)	Refrigeration & air conditioning	Foams	Fire pro- tection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
ODS	3 912,6	2 057,8	-255,4	243,7	15,1			-320,7	5 653,1
CFC	3 048,0	872,5		243,7					4 164,2
CFC-11	77,6	407,2		34,9					519,8
CFC-12	2 620,4	465,3		186,7					3 272,4
CFC-114				22,1					22,1
CFC-115	349,9								349,9
HCFC	864,6	1 185,3			15,1				2 065,0
HCFC-22	864,6	656,5							1 521,1
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	61,8	212,8	0,3	24,0		4 919,6		77,6	5 296,1
HFC	61,8	212,8	0,3	24,0					298,9
HFC-125	2,8								2,8
HFC-134a	54,9	212,7		24,0					291,6
HFC-143a	4,2								4,2
HFC-152a		0,0		0,0					0,1
HFC-227ea			0,3						0,3
HFC-245fa		0,0							0,0
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		77,6	2 082,9
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	3 974,4	2 270,6	-255,1	267,7	15,1	7 931,6	0,0	-243,0	13 961,3

WALLONIA 1995 (kt CO ₂ -eq)	Refrigeration & air conditioning	Foams	Fire pro- tection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
ODS	2 183,4	1 977,3	-144,3	117,1	8,5			-11,9	4 130,1
CFC	1 714,5	486,6		117,1					2 318,2
CFC-11	43,8	223,9		15,6					283,3
CFC-12	1 473,1	262,8		89,0					1 824,8
CFC-114				12,5					12,5
CFC-115	197,6								197,6
HCFC	468,9	1 490,7			8,5				1 968,1
HCFC-22	468,9	1 028,8			8,5				1 497,7
HCFC-141b		1,1							9,6
HCFC-142b		460,8							460,8
Halons			-144,3						-144,3
Halon 1211			-9,3						-9,3
Halon 1301			-135,0						-135,0
Other ODS								-11,9	-11,9
CCl ₄								-0,4	-0,4
CH ₃ Br								-11,5	-11,5
CRF	31,5	112,6	0,2	13,6				50,9	208,7
HFC	31,5	112,6	0,2	13,6					157,9
HFC-125	1,4								1,4
HFC-134a	28,0	112,6		13,5					154,1
HFC-143a	2,1								2,1
HFC-152a		0,0		0,0					0,0
HFC-227ea			0,2						0,2
HFC-245fa		0,0							0,0
SF6								50,9	50,9
General total	2 214,9	2 089,9	-144,1	130,6	8,5	0,0	0,0	38,9	4 338,9

BRUSSELS 1995 (kt CO ₂ -eq)	Refrigeration & air conditioning	Foams	Fire pro- tection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
ODS	628,0	150,6	-41,4	33,6	2,4			-0,4	772,9
CFC	493,4	139,1		33,6					666,0
CFC-11	12,6	63,6		4,5					80,7
CFC-12	424,0	75,5		25,6					525,0
CFC-114				3,6					3,6
CFC-115	56,8								56,8
HCFC	134,7	11,6			2,4				148,7
HCFC-22	134,7								134,7
HCFC-141b		0,1			2,4				2,6
HCFC-142b		11,5							11,5
Halons			-41,4						-41,4
Halon 1211			-2,7						-2,7
Halon 1301			-38,8						-38,8
Other ODS								-0,4	-0,4
CCl ₄								0,0	0,0
CH ₃ Br								-0,3	-0,3
CRF	9,9	31,4	0,1	3,9				6,0	51,2
HFC	9,9	31,4	0,1	3,9					45,2
HFC-125	0,4								0,4
HFC-134a	8,8	31,4		3,9					44,1
HFC-143a	0,6								0,6
HFC-152a		0,0		0,0					0,0
HFC-227ea			0,1						0,1
HFC-245fa		0,0							0,0
SF6								6,0	6,0
General total	637,9	182,0	-41,4	37,5	2,4	0,0	0,0	5,6	824,1

7.5 Emissions in kt CO₂-eq in 1990

Although the base year for F-gases in the Kyoto Protocol is 1995 and the F-gas emission inventory is established for the years 1995-2016, an estimate of the F-gas emissions in t CO₂-eq for the 'CRF gases' has also been made for the year 1990.

These 1990 emissions are estimated by using for 'chemical industry' the actual emission figures for this year (which are available) and for the other source categories the emissions figures for the year 1995, taking into account the fact that certain pollutants were only used after 1990 (from 1992 for R134a and from 1994 for R125 and R143a).

The 1990 emissions of the CRF gases by region are hence estimated as follows:

Flanders: 3 756,27 kt CO₂-eq

Wallonia: 50,86 kt CO₂-eq

Brussels: 5,95 kt CO₂-eq

Belgium: 3 813,08 kt CO₂-eq

7.6 Emissions in t CFC-11-eq in 2016

BELGIUM 2016 (t CFC11-eq)	Refrigeration & air conditioning	Foams	Fire pro- tection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
CFC	0,05	105,60							105,65
CFC-11	0,01	50,96							50,97
CFC-12	0,03	54,64							54,67
CFC-115	0,00								0,00
HCFC	0,96	10,76							11,72
HCFC-22	0,95								0,95
HCFC-124	0,00								0,00
HCFC-141b		1,09							1,09
HCFC-142b	0,01	9,67							9,67
Halons		23,94							23,94
Halon 1211		0,46							0,46
Halon 1301		23,48							23,48
Other ODS								1,29	1,29
CH3Br								1,29	1,29
General total	1,00	116,36	23,94	0,00	0,00	0,00	0,00	1,29	142,59

FLANDERS 2016 (t CFC11-eq)	Refrigeration & air conditioning	Foams	Fire pro- tection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
CFC	0,03	60,71							60,74
CFC-11	0,01	29,30							29,30
CFC-12	0,02	31,41							31,43
CFC-115	0,00								0,00
HCFC	0,55	6,18							6,74
HCFC-22	0,55								0,55
HCFC-124	0,00								0,00
HCFC-141b		0,63							0,63
HCFC-142b	0,00	5,56							5,56
Halons		13,76							13,76
Halon 1211		0,26							0,26
Halon 1301		13,50							13,50
Other ODS								1,29	1,29
CH3Br								1,29	1,29
General total	0,58	66,89	13,76	0,00	0,00	0,00	0,00	1,29	82,52

WALLONIA 2016 (t CFC11-eq)	Refrigeration & air conditioning	Foams	Fire pro- tection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
CFC	0,01	33,76							33,77
CFC-11	0,00	16,29							16,30
CFC-12	0,01	17,47							17,48
CFC-115	0,00								0,00
HCFC	0,31	3,44							3,75
HCFC-22	0,30								0,30
HCFC-124	0,00								0,00
HCFC-141b		0,35							0,35
HCFC-142b	0,00	3,09							3,09
Halons		7,65							7,65
Halon 1211		0,15							0,15
Halon 1301		7,51							7,51
General total	0,32	37,20	7,65	0,00	0,00	0,00	0,00	0,00	45,17

BRUSSELS 2016 (t CFC11-eq)	Refrigeration & air conditioning	Foams	Fire pro- tection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
CFC	0,00	11,13							11,14
CFC-11	0,00	5,37							5,37
CFC-12	0,00	5,76							5,76
CFC-115	0,00								0,00
HCFC	0,10	1,13							1,24
HCFC-22	0,10								0,10
HCFC-124	0,00								0,00
HCFC-141b		0,12							0,12
HCFC-142b	0,00	1,02							1,02
Halons			2,52						2,52
Halon 1211			0,05						0,05
Halon 1301			2,48						2,48
General total	0,11	12,27	2,52	0,00	0,00	0,00	0,00	0,03	14,90

7.7 Emissions in t CFC-11-eq in 1995

BELGIUM 1995 (t CFC11-eq)	Refrigeration & air conditioning	Foams	Fire pro- tection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
CFC	672,78	443,10		69,39			0,00		1 185,27
CFC-11	66,37	343,89		27,23			0,00		437,50
CFC-12	557,72	99,20		37,18					694,10
CFC-114				4,98					4,98
CFC-115	48,69								48,69
HCFC	48,59	111,48			5,50				165,57
HCFC-22	48,59	55,77							104,36
HCFC-141b		24,14			5,50				29,64
HCFC-142b		31,57							31,57
Halons			112,95						112,95
Halon 1211			4,95						4,95
Halon 1301			108,00						108,00
Other ODS							186,86	186,86	
CCl4							32,10	32,10	
CH3Br							154,76	154,76	
General total	721,36	554,58	112,95	69,39	5,50	0,00	0,00	186,86	1 650,65

FLANDERS 1995 (t CFC11-eq)	Refrigeration & air conditioning	Foams	Fire pro- tection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
CFC	390,14	259,04		43,21					692,39
CFC-11	38,43	201,59		17,28					257,31
CFC-12	323,51	57,44		23,05					404,00
CFC-114				2,88					2,88
CFC-115	28,20								28,20
HCFC	28,61	60,39			3,18				92,19
HCFC-22	28,61	21,73							50,34
HCFC-141b		23,89			3,18				27,07
HCFC-142b		14,78							14,78
Halons			65,40						65,40
Halon 1211			2,87						2,87
Halon 1301			62,54						62,54
Other ODS							179,89	179,89	
CCl4							30,84	30,84	
CH3Br							149,05	149,05	
General total	418,75	319,43	65,40	43,21	3,18	0,00	0,00	179,89	1 029,87

WALLONIA 1995 (t CFC11-eq)	Refrigeration & air conditioning	Foams	Fire pro- tection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
CFC	219,49	143,27		20,34					383,09
CFC-11	21,70	110,82		7,73					140,26
CFC-12	181,86	32,44		10,98					225,28
CFC-114				1,63					1,63
CFC-115	15,92								15,92
HCFC	15,52	50,66			1,80				67,98
HCFC-22	15,52	34,05							49,56
HCFC-141b		0,23			1,80				2,03
HCFC-142b		16,38							16,38
Halons			36,94						36,94
Halon 1211			1,62						1,62
Halon 1301			35,32						35,32
Other ODS							6,67	6,67	
CCl4							1,12	1,12	
CH3Br							5,55	5,55	
General total	235,01	193,93	36,94	20,34	1,80	0,00	0,00	6,67	494,68

BRUSSELS 1995 (t CFC11-eq)	Refrigeration & air conditioning	Foams	Fire pro- tection	Aerosols	Solvents	Chemical industry	Electro- nics industry	Other	General total
CFC	63,15	40,79		5,84					109,79
CFC-11	6,23	31,48		2,22					39,93
CFC-12	52,34	9,32		3,15					64,82
CFC-114				0,47					0,47
CFC-115	4,57								4,57
HCFC	4,46	0,43			0,52				5,40
HCFC-22	4,46								4,46
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	67,61	41,22	10,61	5,84	0,52	0,00	0,00	0,29	126,10

7.8 Emission evolution in Belgium

7.8.1 Evolution of emissions by gas

Figure 32 shows the evolution of the emissions in tonnes, in Belgium, by category of gas. After a decrease for 7 years, emissions have increased in 2016, because of SF6.

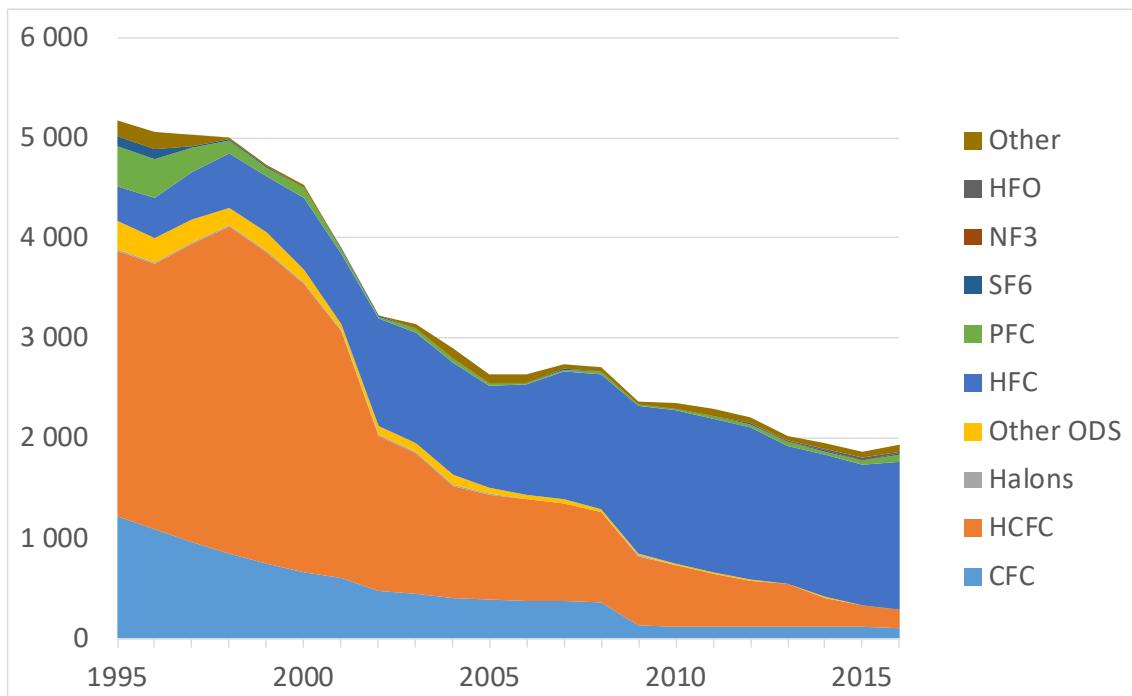


Figure 32: Evolution of the F-gas emissions by type of gas in Belgium (tonnes)

Figure 33 shows that R22 was the dominating substance in the nineties and up to 2008, when R134a took over that role.

The main substance in tonnes used to be HCFC-22, later it became HFC-134a.

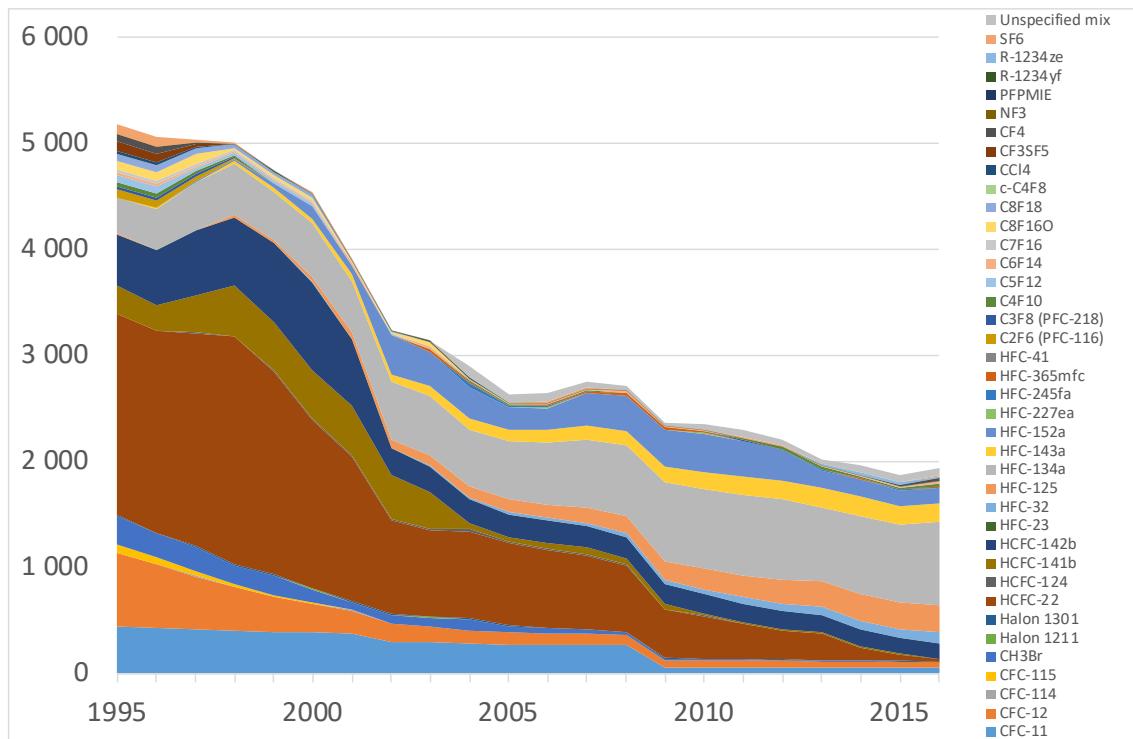


Figure 33: Evolution of the F-gas emissions by substance in Belgium (tonnes)

In terms of CO₂ equivalent, emissions increase in 2016, because of the contribution of CRF gases (the gases of the Kyoto Protocol) (Figure 34).

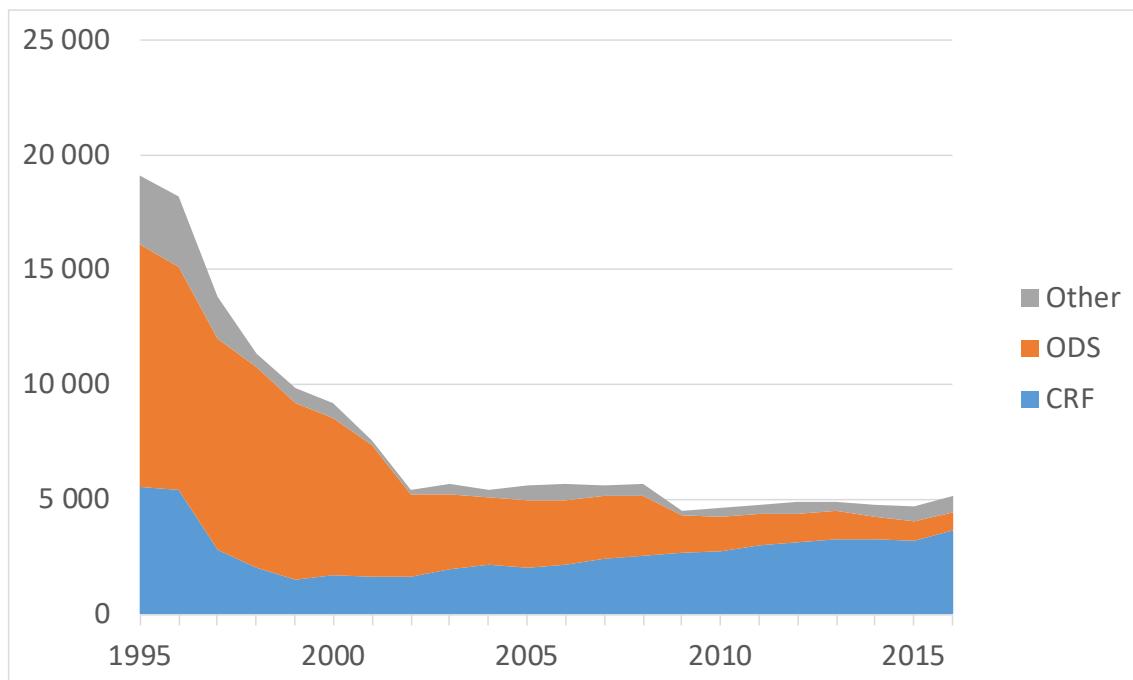


Figure 34: Evolution of the F-gas emissions per gas category in Belgium (kt CO₂-eq)

Figure 35 shows the evolution for the F-gases of the Kyoto protocol (the 'CRF gases'). HFCs as well as PFCs and SF6 have their emissions rising in 2016.

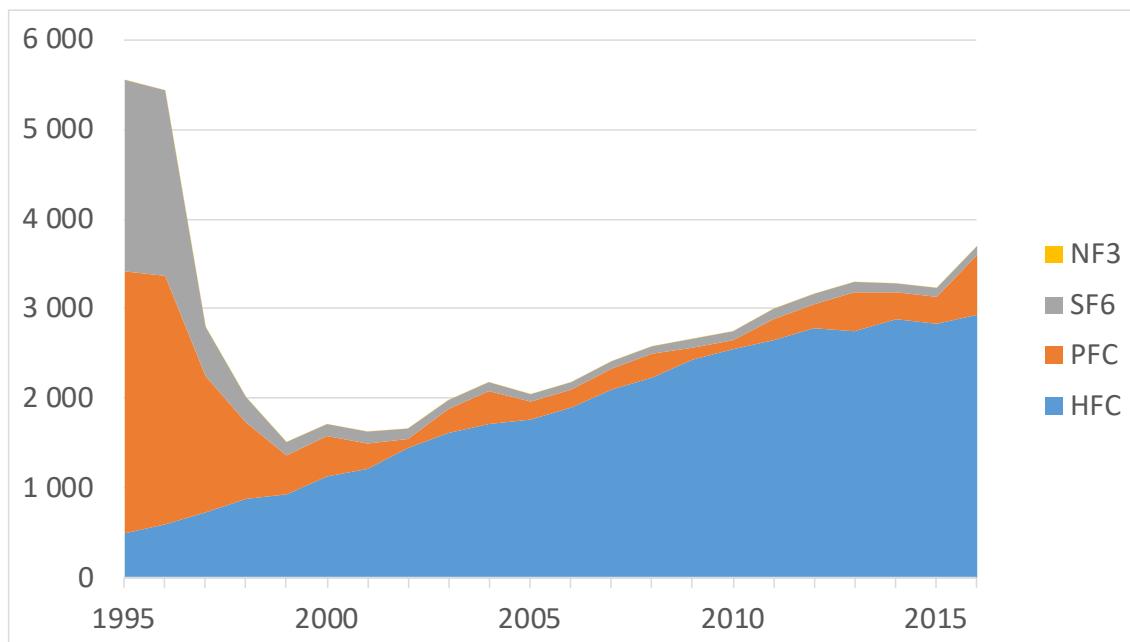


Figure 35: Evolution of the Kyoto F-gas emissions per gas category in Belgium (kt CO2-eq)

On Figure 36, notable is the contribution of SF6, as well as of PFCs C5F12, C4F10, C3F8, C2F6 and CF4, in 1995, and the predominance of HFCs R143a, R134a and R125 in the last decade.

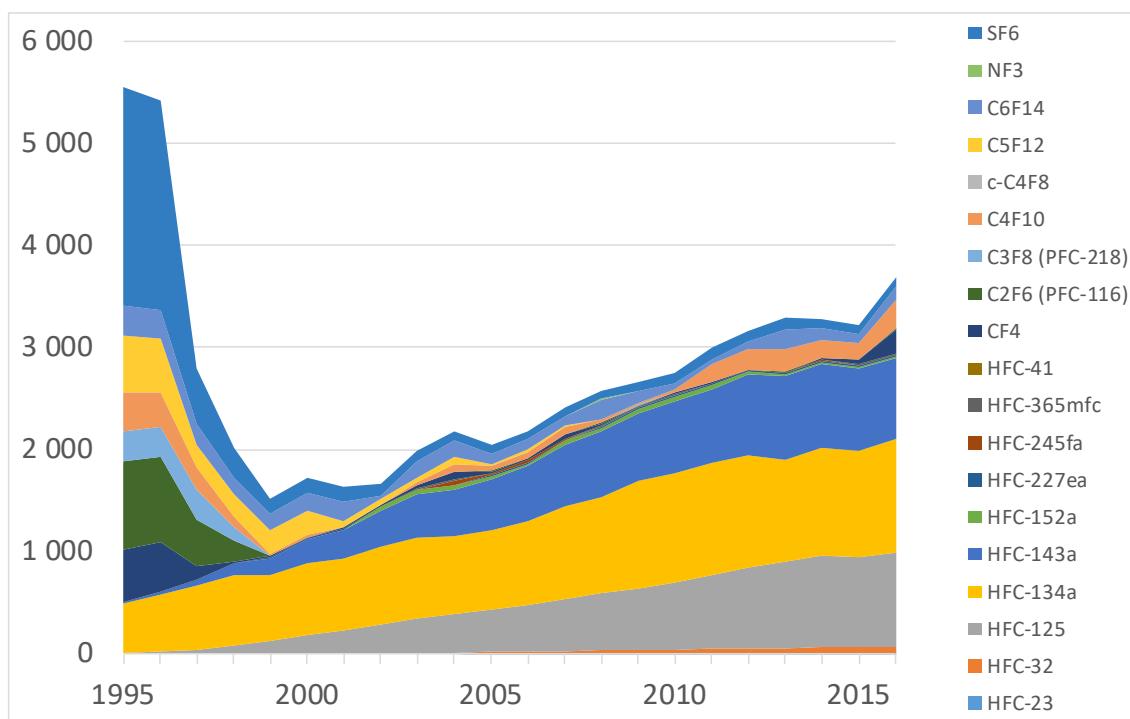


Figure 36: Evolution of the Kyoto F-gas emissions per substance in Belgium (kt CO2-eq)

The corresponding values are given in Table 18 (in tonnes) and Table 19 (in kt CO₂-eq).

Table 18: Evolution of emissions by substance in Belgium, in tonnes

(tonnes)	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
ODS	4 169,9	3 686,1	1 500,3	742,1	656,7	586,9	551,9	408,7	335,4	286,4
CFC	1 217,7	663,9	387,8	119,6	116,9	114,4	112,2	109,8	107,8	105,7
CFC-11	437,5	382,9	271,1	53,4	52,9	52,5	52,1	51,7	51,4	51,0
CFC-12	694,1	265,2	115,8	66,1	64,0	61,9	60,1	58,1	56,4	54,7
CFC-114	5,0	4,9	0,4	0,0	0,0	0,0				
CFC-115	81,2	10,8	0,6	0,1	0,1	0,0	0,0	0,0	0,0	0,0
HCFC	2 652,6	2 880,8	1 047,9	607,0	524,4	457,7	427,2	287,8	220,5	176,1
HCFC-22	1 897,4	1 576,6	775,1	404,9	331,1	272,4	248,5	116,6	55,2	17,2
HCFC-124		17,8	17,1	7,4	5,4	3,9	3,1	1,6	1,1	0,2
HCFC-141b	269,5	454,7	36,1	10,3	10,3	10,2	10,1	10,1	10,0	9,9
HCFC-142b	485,7	831,8	219,6	184,4	177,6	171,3	165,5	159,5	154,2	148,8
Halons	12,5	12,5	6,6	4,2	3,3	4,9	3,1	2,9	3,1	2,5
Halon 1211	1,7	1,7	0,7	0,2	0,2	0,2	0,2	0,2	0,2	0,2
Halon 1301	10,8	10,8	5,9	4,0	3,1	4,7	2,9	2,8	2,9	2,3
Other ODS	287,1	129,0	58,0	11,3	12,1	9,8	9,3	8,2	4,0	2,1
CCl4	29,2	0,7	0,7	0,7	0,7	0,7	0,7	0,7		
CH3Br	257,9	128,3	57,3	10,6	11,4	9,1	8,7	7,5	4,0	2,1
CRF	750,0	769,6	1 048,7	1 558,0	1 568,4	1 557,3	1 416,8	1 465,0	1 439,1	1 558,3
HFC	346,4	714,6	1 023,4	1 541,5	1 538,0	1 521,3	1 363,9	1 426,6	1 400,7	1 475,2
HFC-125	1,3	49,3	117,1	189,1	208,0	228,1	243,3	257,3	254,3	263,7
HFC-134a	342,5	496,4	549,9	751,4	763,5	763,8	697,1	735,6	727,6	778,0
HFC-143a	1,5	50,9	112,2	155,9	164,2	176,9	182,6	185,7	179,5	177,3
HFC-152a	0,8	112,2	205,4	370,1	331,9	281,0	161,4	154,5	140,9	146,6
HFC-227ea	0,2	1,5	3,8	4,1	3,4	3,3	3,6	4,3	5,7	5,2
HFC-23			0,1	0,1	0,1	0,2	0,1	0,1	0,1	0,3
HFC-245fa	0,0	0,1	10,6	0,6	0,6	0,9	0,8	0,8	0,8	0,7
HFC-32		4,4	19,3	50,2	59,1	65,2	74,0	83,2	83,7	93,8
HFC-365mfc			4,9	19,9	7,1	1,9	0,9	4,9	8,3	9,5
HFC-41				0,0	0,0	0,0	0,0	0,0	0,0	0,0
PFC	309,8	48,7	21,3	11,9	25,4	31,1	47,7	34,2	34,3	78,8
C2F6 (PFC-116)	71,8		1,0	0,1	0,1	0,3	0,3	0,3	0,3	0,5
C3F8 (PFC-218)	33,4	0,0	0,3	0,4	0,3	0,3	0,2	0,2	0,2	0,2
C4F10	41,8	2,0	5,4	2,6	19,6	23,1	25,6	19,8	16,9	31,6
C5F12	60,6	26,5	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
C6F14	32,9	19,2	11,0	7,0	4,0	6,7	20,6	12,3	10,4	14,1
c-C4F8				0,0	0,0	0,0	0,0	0,0	0,0	0,0
CF4	69,2	1,0	2,6	1,8	1,3	0,6	1,0	1,6	6,3	32,5
SF6	93,8	6,3	4,0	4,5	4,9	4,8	5,1	4,2	4,0	4,2
NF3				0,1	0,1	0,1	0,1	0,0	0,0	0,0
Other	258,2	75,4	82,0	48,3	67,4	59,2	52,1	82,0	95,4	93,6
PFC	96,3	49,7								
C7F16	23,9	9,4								
C8F18	72,5	40,4								
HFO							8,7	21,8	26,4	18,6
R-1234yf									0,1	0,9
R-1234ze							8,7	21,8	26,3	17,7
Other	161,9	25,6	82,0	48,3	67,4	59,2	43,3	60,3	69,1	75,0
C8F16O	71,0	25,6								
CF3SF5	90,9									
PFPMIE				0,6	0,5	0,7	0,5	0,6	1,0	1,0
Unspecified mix			82,0	47,6	66,9	58,4	42,8	59,7	68,1	74,0
General total	5 178,1	4 531,1	2 631,0	2 348,4	2 292,5	2 203,3	2 020,7	1 955,8	1 869,9	1 938,4

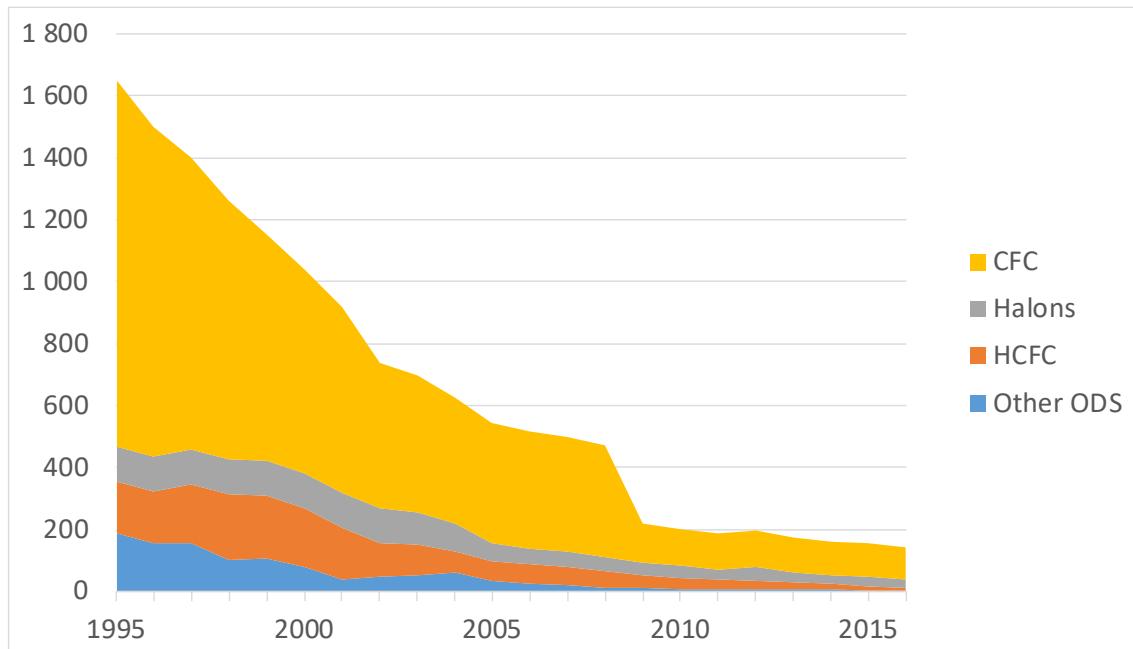
Table 19: Evolution of emissions by substance in Belgium, in kt CO2-eq

(kt CO2-eq)	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
ODS	10 556,2	6 824,5	2 898,9	1 493,3	1 372,6	1 186,5	1 189,0	948,5	821,8	756,7
CFC	7 148,5	3 039,9	1 492,8	644,3	625,5	607,9	592,1	575,4	560,9	545,8
CFC-11	883,7	773,5	547,5	107,9	106,9	106,0	105,3	104,4	103,7	103,0
CFC-114	38,2	37,9	3,0	0,0	0,0					
CFC-115	604,4	80,3	4,5	0,6	0,4	0,3	0,3	0,1	0,1	0,0
CFC-12	5 622,2	2 148,3	937,7	535,8	518,2	501,6	486,6	470,9	457,0	442,9
HCFC	4 181,8	4 386,2	1 716,6	1 019,0	882,9	773,0	722,3	491,4	379,4	305,9
HCFC-124		8,6	8,2	3,5	2,6	1,9	1,5	0,8	0,5	0,1
HCFC-141b	140,4	236,9	18,8	5,4	5,3	5,3	5,3	5,2	5,2	5,2
HCFC-142b	887,9	1 520,4	401,4	337,0	324,7	313,1	302,5	291,6	281,9	272,0
HCFC-22	3 153,5	2 620,2	1 288,2	673,0	550,3	452,8	413,0	193,8	91,8	28,7
Halons	-441,1	-441,1	-238,8	-156,4	-121,3	-182,7	-114,4	-108,7	-113,5	-92,3
Halon 1211	-28,5	-28,5	-12,3	-4,1	-3,3	-3,5	-3,1	-3,0	-3,0	-2,6
Halon 1301	-412,7	-412,7	-226,5	-152,3	-118,0	-179,2	-111,3	-105,7	-110,5	-89,7
Other ODS	-333,0	-160,4	-71,8	-13,5	-14,5	-11,6	-11,1	-9,6	-5,0	-2,7
CCI4	-11,1	-0,3	-0,3	-0,3	-0,3	-0,3	-0,3	-0,3		
CH3Br	-321,9	-160,1	-71,5	-13,2	-14,2	-11,4	-10,8	-9,3	-5,0	-2,7
CRF	5 556,0	1 721,6	2 048,1	2 754,8	2 993,9	3 165,9	3 298,1	3 281,5	3 226,2	3 693,1
HFC	502,0	1 131,4	1 764,6	2 544,8	2 653,8	2 776,1	2 749,5	2 878,7	2 834,1	2 939,2
HFC-125	4,6	172,4	409,8	661,9	728,0	798,3	851,7	900,7	890,0	923,0
HFC-134a	489,8	709,8	786,4	1 074,6	1 091,8	1 092,3	996,9	1 052,0	1 040,5	1 112,6
HFC-143a	6,9	227,3	501,7	696,9	734,0	790,7	816,3	830,0	802,4	792,6
HFC-152a	0,1	13,9	25,5	45,9	41,2	34,8	20,0	19,2	17,5	18,2
HFC-227ea	0,6	4,9	12,3	13,1	10,9	10,8	11,6	14,0	18,2	16,9
HFC-23			1,0	2,2	1,9	2,8	1,4	2,0	1,7	4,3
HFC-245fa	0,0	0,1	10,9	0,6	0,7	0,9	0,8	0,8	0,8	0,7
HFC-32		3,0	13,1	33,9	39,9	44,0	50,0	56,2	56,5	63,3
HFC-365mfc			3,9	15,8	5,7	1,5	0,7	3,9	6,6	7,5
HFC-41				0,0	0,0	0,0	0,0	0,0	0,0	0,0
PFC	2 914,3	446,1	192,8	106,6	225,5	278,2	431,6	307,0	299,9	658,6
C2F6 (PFC-116)	875,9		11,6	1,7	1,7	3,2	3,3	3,4	4,2	5,5
C3F8 (PFC-218)	294,5	0,2	2,4	3,4	2,8	2,4	2,1	1,9	2,1	1,8
C4F10	370,6	17,7	47,9	23,2	174,0	205,0	227,2	175,2	150,0	279,8
C5F12	555,5	242,6	8,8	0,0	0,0	0,0	0,0	0,0	0,0	0,0
C6F14	306,1	178,1	102,7	64,7	37,1	62,3	191,5	114,3	96,9	131,0
c-C4F8				0,3	0,2	0,4	0,2	0,1	0,1	0,2
CF4	511,7	7,4	19,3	13,4	9,7	4,8	7,2	12,0	46,6	240,2
SF6	2 139,7	144,1	90,7	102,0	112,1	110,4	115,8	95,2	91,4	94,7
NF3				1,3	2,5	1,1	1,2	0,7	0,8	0,7
Other	3 012,0	635,9	687,0	384,0	382,6	565,2	407,3	564,5	643,0	682,9
PFC	763,5	395,0								
C7F16	183,8	72,1								
C8F18	579,6	322,9								
HFO							0,1	0,1	0,2	0,1
R-1234yf									0,0	0,0
R-1234ze							0,1	0,1	0,2	0,1
Other	2 248,5	241,0	687,0	384,0	382,6	565,2	407,2	564,4	642,8	682,8
C8F16O	667,1	241,0								
CF3SF5	1 581,5									
PFPMIE				6,3	4,6	7,2	5,2	5,9	9,8	9,8
Unspecified mix			687,0	377,8	378,0	558,0	402,0	558,4	633,0	673,0
General total	19 124,2	9 182,0	5 634,0	4 632,1	4 749,1	4 917,6	4 894,3	4 794,5	4 691,0	5 132,7

The evolution of emissions of ozone depleting substances expressed in tonnes CFC-11 equivalents is shown on Table 20, Figure 37 (by gas category) and Figure 38 (by substance). It can be remembered that the decrease 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 20: Evolution of emissions of ozone depleting substances in Belgium, in t CFC11-eq

(t CFC-11 eq)	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
CFC	1 185,27	659,54	387,58	119,61	116,92	114,42	112,21	109,83	107,78	105,65
CFC-11	437,50	382,92	271,06	53,42	52,91	52,48	52,11	51,69	51,35	50,97
CFC-114	4,98	4,94	0,39	0,00	0,00	0,00				
CFC-115	48,69	6,47	0,36	0,05	0,04	0,02	0,02	0,01	0,01	0,00
CFC-12	694,10	265,22	115,77	66,14	63,97	61,92	60,08	58,13	56,42	54,67
HCFC	165,57	191,18	61,25	35,55	31,00	27,32	25,61	17,92	14,18	11,72
HCFC-124	0,39	0,38	0,16	0,12	0,08	0,07	0,07	0,04	0,03	0,00
HCFC-141b	29,64	50,01	3,97	1,13	1,13	1,12	1,11	1,11	1,10	1,09
HCFC-142b	31,57	54,06	14,27	11,98	11,55	11,13	10,76	10,37	10,02	9,67
HCFC-22	104,36	86,71	42,63	22,27	18,21	14,98	13,67	6,41	3,04	0,95
Halons	112,95	112,95	61,41	40,57	31,46	47,51	29,66	28,19	29,44	23,94
Halon 1211	4,95	4,95	2,14	0,71	0,58	0,60	0,54	0,53	0,51	0,46
Halon 1301	108,00	108,00	59,27	39,85	30,89	46,91	29,12	27,67	28,93	23,48
Other ODS	186,86	77,73	35,13	7,10	7,58	6,22	5,94	5,23	2,38	1,29
CCl4	32,10	0,74	0,74	0,74	0,74	0,74	0,74	0,74		
CH3Br	154,76	76,99	34,38	6,36	6,84	5,47	5,19	4,48	2,38	1,29
General total	1 650,65	1 041,41	545,37	202,84	186,97	195,48	173,42	161,18	153,79	142,59

**Figure 37: Evolution of ozone depleting substances, by gas category, in Belgium (t CFC11-eq)**

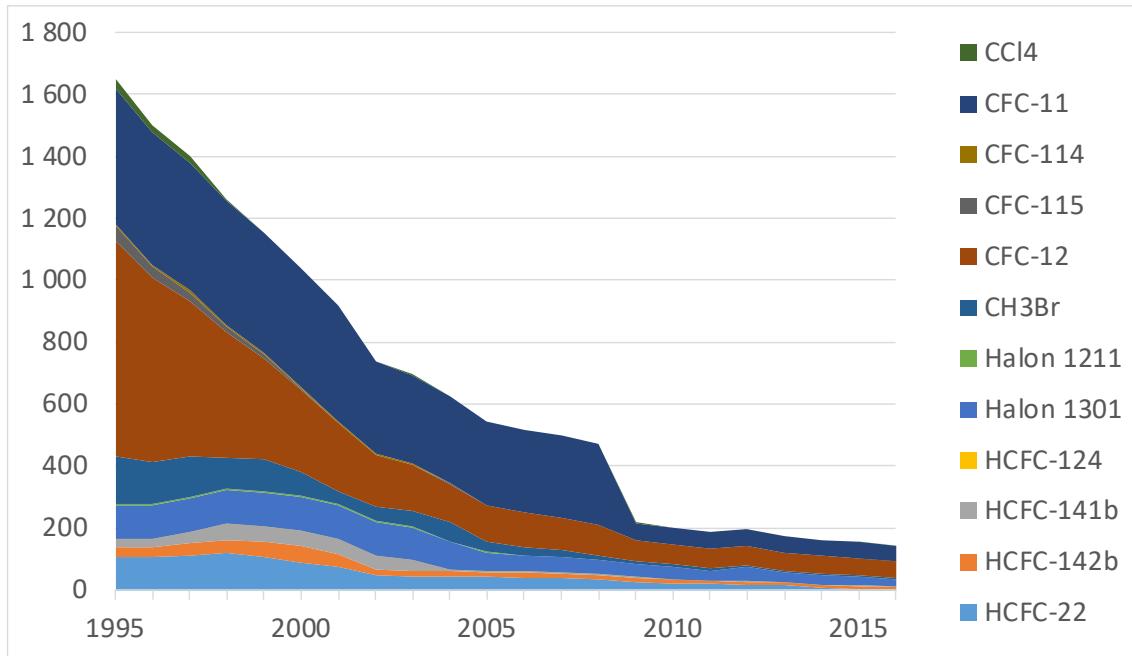


Figure 38: Evolution of ozone depleting substances, by substance, in Belgium (t CFC11-eq)

7.8.2 Evolution of emissions by source

The evolution by source is given in Table 21 in tonnes and Table 22 in kt CO₂-eq.

Table 21: Evolution of total emissions per source, in tonnes

(tonnes)	1995	2000	2005	2010	2013	2014	2015	2016
01. Dom. refrig. - Coolant	47,3	45,2	28,5	1,4	1,5	1,5	1,4	0,9
02. Dom. refrig. - Foam	286,1	282,1	210,8	0,4	0,4	0,4	0,4	0,3
03. RAC & heat pumps	20,7	90,1	64,0	72,1	103,5	112,9	105,7	116,9
04. Car airco	28,6	76,6	172,3	293,2	331,0	349,8	346,7	341,0
05. Bus&Coach airco	17,7	18,6	24,4	31,5	35,5	36,5	37,7	38,9
06. Trucks airco		5,1	15,9	32,3	40,2	40,4	42,0	44,5
07. Refrigerated transport	0,4	3,4	8,4	13,1	12,9	13,7	11,4	9,3
08. Passenger rail transport		2,5	2,6	3,1	2,4	2,2	2,1	2,3
10. Ind.&comm. refrig.	1 540,8	1 374,1	1 207,0	1 022,1	839,8	740,1	663,0	671,1
11. Closed cell foam	1 876,2	1 806,1	603,4	704,4	456,3	446,2	454,6	454,9
12. PU cans	250,0	204,2	34,1	25,4	26,6	40,0	21,0	25,4
13. Aerosols MDI	69,4	66,5	32,4	32,2	33,6	33,8	33,9	34,1
14. Other aerosols	29,3	58,5	36,7	32,9	25,0	24,6	30,5	32,0
15. CCl4	29,2	0,7	0,7	0,7	0,7	0,7		
16. Methylbr.	257,9	128,3	57,3	10,6	8,7	7,5	4,0	2,1
17. SF6 electr. Sector	0,3	0,4	0,5	0,6	0,5	0,5	0,4	0,5
18. SF6 in glass sector	3,5	3,8	3,1	3,8	4,4	3,5	3,5	3,4
19. Fire Extinguishers	12,6	14,0	10,5	8,5	6,8	6,8	7,2	6,5
20. Chemical Ind	655,9	124,0	101,6	58,4	89,6	93,1	102,2	151,5
21. Semiconductors			1,5	1,9	1,6	1,6	2,1	2,8
22. Nike shoes	2,1	2,1	0,3					
23. Solvents	50,0	225,0	15,0					
Total	5 178,1	4 531,1	2 631,0	2 348,4	2 020,7	1 955,8	1 869,9	1 938,4

Stationary and mobile refrigeration and air conditioning are the main sources, together with closed cell foams.

Table 22: Evolution of CRF gas emissions per source, in kt CO2-eq

(kt CO2-eq)	1995	2000	2005	2010	2013	2014	2015	2016
01. Dom. refrig. - Coolant	0,1	0,4	0,6	2,0	2,1	2,1	2,1	1,3
02. Dom. refrig. - Foam	0,0	0,1	0,1	0,4	0,4	0,4	0,4	0,3
03. RAC & heat pumps	0,1	35,3	46,7	135,8	199,2	220,2	209,0	234,0
04. Car airco	21,0	109,5	246,4	419,2	473,3	500,1	495,7	487,6
05. Bus&Coach airco	5,6	26,6	34,9	45,1	50,8	52,3	53,9	55,6
06. Trucks airco		7,3	22,8	46,1	57,5	57,7	60,1	63,2
07. Refrigerated transport	1,5	10,6	26,6	41,3	40,8	44,0	36,8	30,0
08. Passenger rail transport		3,7	3,8	4,6	3,5	3,2	3,0	3,3
10. Ind.&comm. refrig.	74,9	594,7	1 159,8	1 637,5	1 767,8	1 839,3	1 796,8	1 865,2
11. Closed cell foam		29,0	74,1	115,2	56,3	59,9	65,5	68,2
12. PU cans	356,8	239,0	48,0	3,8	4,0	4,7	4,9	23,6
13. Aerosols MDI		0,4	39,7	46,2	48,4	48,6	48,8	49,1
14. Other aerosols	41,5	70,3	50,3	34,6	34,0	33,2	41,1	42,3
17. SF6 electr. Sector	7,8	9,3	10,8	12,9	12,4	11,4	9,9	10,6
18. SF6 in glass sector	79,8	87,8	69,9	86,2	101,0	80,4	78,9	77,4
19. Fire Extinguishers	0,6	4,9	12,4	14,0	12,0	12,5	13,3	12,9
20. Chemical Ind	4 919,6	445,9	175,6	96,7	422,7	299,6	293,1	645,7
21. Semiconductors			17,8	13,0	11,8	11,9	13,0	22,7
22. Nike shoes	46,9	47,0	8,0					
Total	5 556,0	1 721,6	2 048,1	2 754,8	3 298,1	3 281,5	3 226,2	3 693,1

Figure 39 and Table 23 present the emissions of the Kyoto protocol gases in the CRF (Common Reporting Format) of the UNFCCC reporting, in terms of CO₂ equivalents. Here, 'Commercial refrigeration' includes industrial refrigeration and stationary air conditioning. Striking are the rise in emissions and the share of stationary and mobile refrigeration and air conditioning in the current emissions.

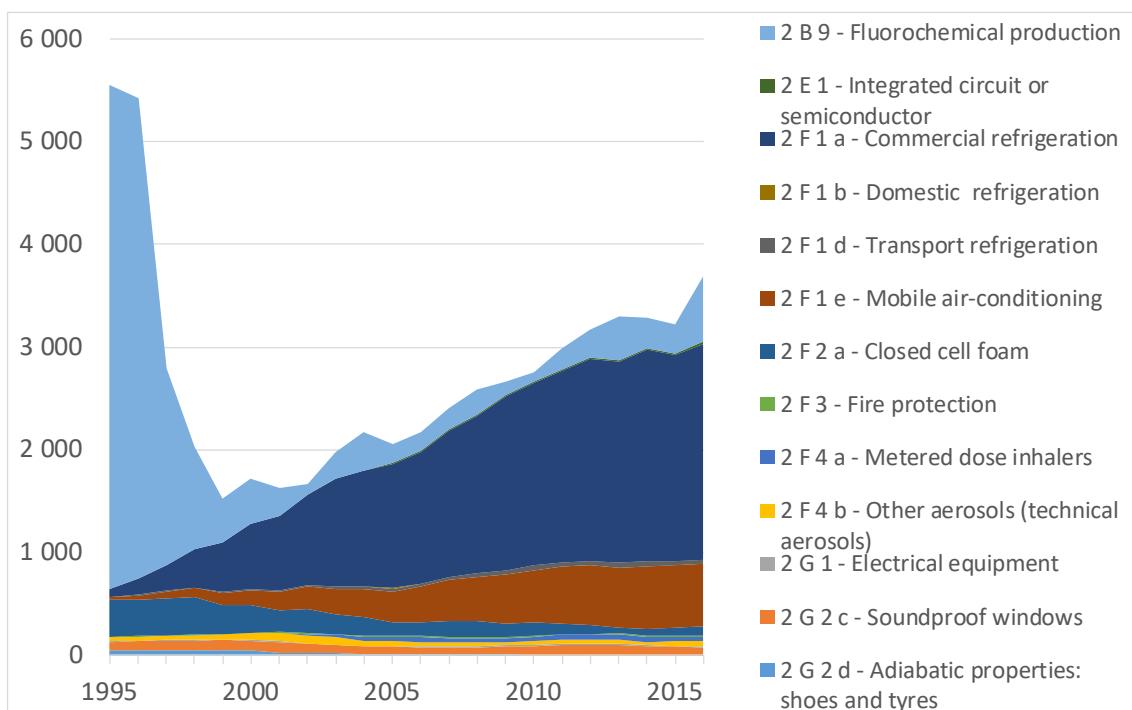
**Figure 39: Evolution of Kyoto gas emissions by source (kt CO2 eq)**

Table 23: Evolution of the Kyoto gas emissions by source, in kt CO2-eq

(kt CO2-eq)	CRF Name	1995	2000	2005	2010	2013	2014	2015	2016
2 B 9	Fluorochemical production	4 919,6	445,9	175,6	96,7	422,7	299,6	293,1	645,7
2 E 1	Integrated circuit or semiconductor			17,8	13,0	11,8	11,9	13,0	22,7
2 F 1 a	Commercial refrigeration	75,0	630,0	1 206,5	1 773,3	1 967,0	2 059,6	2 005,8	2 099,2
2 F 1 b	Domestic refrigeration	0,1	0,4	0,6	2,0	2,1	2,1	2,1	1,3
2 F 1 d	Transport refrigeration	1,5	10,6	26,6	41,3	40,8	44,0	36,8	30,0
2 F 1 e	Mobile air-conditioning	26,6	147,1	307,9	515,1	585,1	613,4	612,8	609,8
2 F 2 a	Closed cell foam	356,8	268,1	122,2	119,5	60,7	65,0	70,8	92,1
2 F 3	Fire protection	0,6	4,9	12,4	14,0	12,0	12,5	13,3	12,9
2 F 4 a	Metered dose inhalers			0,4	39,7	46,2	48,4	48,6	48,8
2 F 4 b	Other aerosols (technical aerosols)	41,5	70,3	50,3	34,6	34,0	33,2	41,1	42,3
2 G 1	Electrical equipment	7,8	9,3	10,8	12,9	12,4	11,4	9,9	10,6
2 G 2 c	Soundproof windows	79,8	87,8	69,9	86,2	101,0	80,4	78,9	77,4
2 G 2 d	Adiabatic properties: shoes and tyres	46,9	47,0	8,0					
Total		5 556,0	1 721,6	2 048,1	2 754,8	3 298,1	3 281,5	3 226,2	3 693,1

(*) This category also includes industrial refrigeration, stationary air conditioning and heat pumps

Conversely, 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).

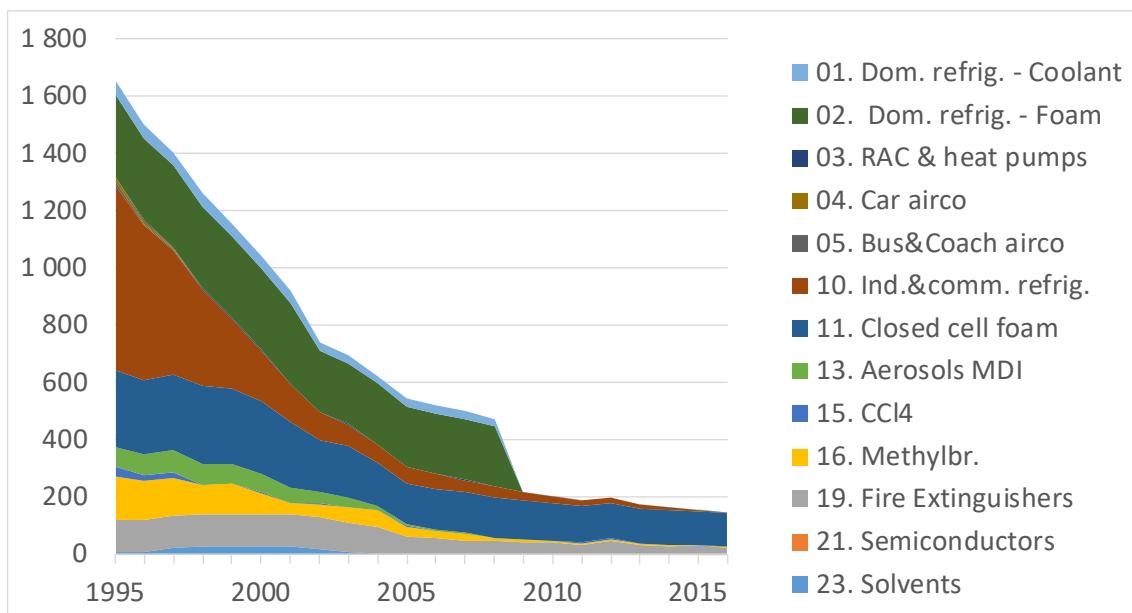
**Figure 40: Evolution of ODS gas emissions by source (t CFC11-eq)**

Table 24: Evolution of the emissions of ODS gases by source, in t CFC11-eq

(t CFC-11 eq)	1995	2000	2005	2010	2013	2014	2015	2016
01. Dom. refrig. - Coolant	47,30	44,98	28,13					
02. Dom. refrig. - Foam	286,07	282,04	210,65	0,00	0,00			
03. RAC & heat pumps	1,14	3,74	2,14					
04. Car airco	13,91							
05. Bus&Coach airco	13,78							
10. Ind.&comm. refrig.	645,23	178,48	56,04	24,59	14,65	6,92	3,40	1,00
11. Closed cell foam	268,51	250,53	145,27	130,51	123,16	120,83	118,57	116,36
13. Aerosols MDI	69,39	66,20	4,94	0,06	0,00			
15. CCl4	32,10	0,74	0,74	0,74	0,74	0,74		
16. Methylbr.	154,76	76,99	34,38	6,36	5,19	4,48	2,38	1,29
19. Fire Extinguishers	112,95	112,95	61,41	40,57	29,66	28,19	29,44	23,94
21. Semiconductors	0,00			0,00	0,00			
23. Solvents	5,50	24,75	1,65					
Total	1 650,65	1 041,41	545,37	202,84	173,42	161,18	153,79	142,59

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 [22]. 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* [23], which itself relies on the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* [24].

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 [23]¹⁴, the greenhouse gas inventory is principally the sum of products of activity data and emission factors. In a simplified way¹⁵:

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

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.

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

¹⁴ Page 6.12.

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

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 [23].

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. [25], 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 approaches¹⁶ 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. 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.

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

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 theorem¹⁷, 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).

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’.

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

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 [23], 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 [22].

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	$\sqrt{E^2 + F^2 + \frac{1}{3,8} E^2 F^2}$	$\frac{(G * D)^2}{(\sum D)^2}$	Note B	$\frac{D}{\sum C}$	$I * F$	$J * E * \sqrt{2}$	$\sqrt{K^2 + L^2}$
2B9a By-product emissions	CF4	511,68	511,68	90%	0%	90%	0,0010%					
2B9a By-product emissions	C2F6	875,85	875,85	26%	0%	26%	0,0002%					
2B9a By-product emissions	C3F8	294,50	294,50	26%	0%	26%	0,0000%					
2B9a By-product emissions	C4F10	333,52	333,52	26%	0%	26%	0,0000%					
2B9a By-product emissions	C5F12	58,04	58,04	26%	0%	26%	0,0000%					
2B9a By-product emissions	SF6	2 005,28	2 005,28	26%	0%	26%	0,0013%					
2B9b Fugitive emissions	C4F10	37,06	37,06	26%	0%	26%	0,0000%					
2B9b Fugitive emissions	C5F12	497,50	497,50	26%	0%	26%	0,0001%					
2B9b Fugitive emissions	C6F14	306,15	306,15	26%	0%	26%	0,0000%					
2E1 Semiconductors	HFC-23	0,00	0,00		100%	100%	0,0000%					
2E1 Semiconductors	CF4	0,00	0,00		100%	100%	0,0000%					
2E1 Semiconductors	C2F6	0,00	0,00		100%	100%	0,0000%	NOT RELEVANT				
2E1 Semiconductors	c-C4F8	0,00	0,00		100%	100%	0,0000%					
2E1 Semiconductors	SF6	0,00	0,00		100%	100%	0,0000%					
2E1 Semiconductors	NF3	0,00	0,00		100%	100%	0,0000%					
2E4 Heat transfer fluid	HFC-32	0,00	0,00		100%	100%	0,0000%					
2E4 Heat transfer fluid	HFC-125	0,00	0,00		100%	100%	0,0000%					
2F1a Commercial refrigeration	HFC-32	0,00	0,00		75%	75%	0,0000%					
2F1a Commercial refrigeration	HFC-125	4,03	4,03		75%	75%	0,0000%					
2F1a Commercial refrigeration	HFC-134a	64,91	64,91		75%	75%	0,0000%					
2F1a Commercial refrigeration	HFC-143a	6,03	6,03		75%	75%	0,0000%					
2F1a Commercial refrigeration	HFC-152a	0,00	0,00		75%	75%	0,0000%					
2F1a Commercial refrigeration	C3F8 (PFC-218)	0,00	0,00		75%	75%	0,0000%					
2F1b Domestic refrigeration	HFC-134a	0,05	0,05		75%	75%	0,0000%					
2F1d Transport refrigeration	HFC-32	0,00	0,00	100%	50%	115%	0,0000%					
2F1d Transport refrigeration	HFC-125	0,57	0,57	100%	50%	115%	0,0000%					
2F1d Transport refrigeration	HFC-134a	0,12	0,12	100%	50%	115%	0,0000%					
2F1d 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	$\sqrt{E^2 + F^2 + \frac{1}{3,8} E^2 F^2}$	$\frac{(G * D)^2}{(\sum D)^2}$	Note B	$\frac{D}{\sum C}$	$I * F$	$J * E * \sqrt{2}$	$\sqrt{K^2 + L^2}$
2 F 1 e Mobile air-conditioning	HFC-32	0,00	0,00	100%	50%	115%	0,0000%					
2 F 1 e Mobile air-conditioning	HFC-125	0,00	0,00	100%	50%	115%	0,0000%					
2 F 1 e Mobile air-conditioning	HFC-134a	26,59	26,59	100%	50%	115%	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%	0,000%	0,000%	0,00%	0,00%	0,000%
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	15%	5%	16%	0,0000%					
2 F 3 Fire protection	HFC-125	0,00	0,00	10%	50%	51%	0,0000%	NOT RELEVANT				
2 F 3 Fire protection	HFC-227ea	0,58	0,58	10%	50%	51%	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	25%	50%	56%	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		200%	200%	0,0000%					
2 G 1 Electrical equipment	SF6	7,75	7,75		50%	50%	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%					
2 G 2 e Laboratory uses	C6F14	0,00	0,00		100%	100%	0,0000%					
Total F-gases		5 556,02	5 556,02				0,0028%					
Total 6 GHG (without LUCF)		146 294,18	146 294,18			Percentage uncertainty in total inventory	0,527%					

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.

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

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 2015 - 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)	2015 emissions	Activity data uncertainty (%)	Emission factor uncertainty (%)	Combined uncertainty	Contribution to Variance by Category in 2015	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Gg CO2 eq	Gg CO2 eq									
		Input data	Input data	Input data	Input data	$\sqrt{E^2 + F^2 + \frac{1}{3,8} E^2 \cdot F^2}$	$\frac{(G * D)^2}{(\sum D)^2}$	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	43,03	26%	0%	26%	0,0000%	-0,003%	0,000%	0,00%	0,01%	0,011%
2B 9 a By-product emissions	C2F6 (PFC-116)	875,85	0,00	90%	0%	90%	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	HFCs	0,00	3,10	26%	0%	26%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2B 9 b Fugitive emissions	C4F10	37,06	149,99	26%	0%	26%	0,0000%	0,001%	0,001%	0,00%	0,04%	0,038%
2B 9 b Fugitive emissions	C5F12	497,50	0,02	26%	0%	26%	0,0000%	-0,003%	0,000%	0,00%	0,00%	0,000%
2B 9 b Fugitive emissions	C6F14	306,15	96,92	26%	0%	26%	0,0000%	-0,001%	0,001%	0,00%	0,02%	0,024%
2E 1 Semiconductors	HFCs	0,00	1,67		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2E 1 Semiconductors	CF4	0,00	3,60		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,002%
2E 1 Semiconductors	C2F6 (PFC-116)	0,00	4,16		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,003%
2E 1 Semiconductors	c-C4F8	0,00	0,15		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2E 1 Semiconductors	SF6	0,00	2,57		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,002%
2E 1 Semiconductors	NF3	0,00	0,85		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2E 4 Heat transfer fluid	HFC-32	0,00	0,00		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2E 4 Heat transfer fluid	HFC-125	0,00	0,00		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2F 1 a Commercial refrigeration	HFC-32	0,00	56,05		75%	75%	0,0000%	0,000%	0,000%	0,03%	0,00%	0,029%
2F 1 a Commercial refrigeration	HFC-125	4,03	872,92		75%	75%	0,0031%	0,006%	0,006%	0,45%	0,00%	0,446%
2F 1 a Commercial refrigeration	HFC-134a	64,91	290,66		75%	75%	0,0003%	0,002%	0,002%	0,12%	0,00%	0,122%
2F 1 a Commercial refrigeration	HFC-143a	6,03	784,10		75%	75%	0,0025%	0,005%	0,005%	0,40%	0,00%	0,399%
2F 1 a Commercial refrigeration	HFC-152a	0,00	0,01		75%	75%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2F 1 a Commercial refrigeration	C3F8 (PFC-218)	0,00	2,06		75%	75%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2F 1 b Domestic refrigeration	HFC-134a	0,05	2,06		75%	75%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2F 1 d Transport refrigeration	HFC-32	0,00	0,39	100%	50%	115%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2F 1 d Transport refrigeration	HFC-125	0,57	14,18	100%	50%	115%	0,0000%	0,000%	0,000%	0,00%	0,01%	0,014%
2F 1 d Transport refrigeration	HFC-134a	0,12	3,87	100%	50%	115%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,004%
2F 1 d Transport refrigeration	HFC-143a	0,86	18,32	100%	50%	115%	0,0000%	0,000%	0,000%	0,01%	0,02%	0,019%

Table 3.2 : Approach 1 uncertainty calculation and reporting for the year 2015 - 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)	2015 emissions	Activity data uncertainty (%)	Emission factor uncertainty (%)	Combined uncertainty	Contribution to Variance by Category in 2015	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Gg CO2 eq	Gg CO2 eq									
		Input data	Input data	Input data	Input data	$\sqrt{E^2 + F^2 + \frac{1}{3,8} E^2 \cdot F^2}$	$\frac{(G * D)^2}{(\sum D)^2}$	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-32	0,00	0,03	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	0,16	100%	50%	115%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 F 1 e Mobile air-conditioning	HFC-134a	26,59	612,56	100%	50%	115%	0,0036%	0,004%	0,004%	0,20%	0,59%	0,626%
2 F 2 a Closed cell foam	HFC-134a	356,73	42,18	15%	5%	16%	0,0000%	-0,002%	0,000%	-0,01%	0,01%	0,010%
2 F 2 a Closed cell foam	HFC-152a	0,06	17,21	15%	5%	16%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,003%
2 F 2 a Closed cell foam	HFC-227ea	0,00	4,02	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	0,82	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	6,56	15%	5%	16%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2 F 3 Fire protection	HFC-125	0,00	1,00	10%	50%	51%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 F 3 Fire protection	HFC-227ea	0,58	12,28	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	48,27	25%	50%	56%	0,0000%	0,000%	0,000%	0,02%	0,01%	0,020%
2 F 4 a Metered dose inhalers	HFC-227ea	0,00	0,56	25%	50%	56%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 F 4 b Technical aerosols	HFC-134a	41,41	40,86		200%	200%	0,0000%	0,000%	0,000%	0,01%	0,00%	0,010%
2 F 4 b Technical aerosols	HFC-152a	0,04	0,24		200%	200%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 G 1 Electrical equipment	SF6	7,75	9,89		50%	50%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2 G 2 c Soundproof windows	SF6	79,77	78,91		100%	100%	0,0000%	0,000%	0,001%	0,01%	0,00%	0,010%
2 G 2 d Adiabatic properties: shoes	SF6	46,93	0,00		100%	100%	0,0000%	0,000%	0,000%	-0,03%	0,00%	0,026%
2 G 2 e Laboratory uses	C6F14	0,00	0,00		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
Total F-gases		5 556,02	3 226,24				0,0097%					0,008%
Total 7 GHGs (without LUCF)		146 294,18	117 443,26			Percentage uncertainty in total inventory	0,984%				Trend uncertainty	0,877%

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.

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

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

Table 3.2: Approach 1 uncertainty calculation and reporting for year 2016 - 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)	2016 emissions	Activity data uncertainty (%)	Emission factor uncertainty (%)	Combined uncertainty	Contribution to Variance by Category in 2016	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Gg CO2 eq	Gg CO2 eq									
		Input data	Input data	Input data	Input data	$\sqrt{E^2 + F^2 + \frac{1}{3,8} E^2 F^2}$	$\frac{(G * D)^2}{(\sum D)^2}$	Note B	$\frac{D}{\sum C}$	$I * F$	$J * E * \sqrt{2}$	$\sqrt{K^2 + L^2}$
2 B 9 a By-product emissions	HFCs	511,68	234,91	26%	0%	26%	0,0000%	-0,001%	0,002%	0,00%	0,06%	0,059%
2 B 9 a By-product emissions	C2F6 (PFC-116)	875,85	0,00	90%	0%	90%	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	C5F12	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	C4F10	37,06	279,81	26%	0%	26%	0,0000%	0,002%	0,002%	0,00%	0,07%	0,070%
2 B 9 b Fugitive emissions	CSF12	497,50	0,02	26%	0%	26%	0,0000%	-0,003%	0,000%	0,00%	0,00%	0,000%
2 B 9 b Fugitive emissions	C6F14	306,15	131,00	26%	0%	26%	0,0000%	-0,001%	0,001%	0,00%	0,03%	0,033%
2 E 1 Semiconductors	HFCs	0,00	4,33		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,003%
2 E 1 Semiconductors	CF4	0,00	5,26		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,004%
2 E 1 Semiconductors	C2F6 (PFC-116)	0,00	5,53		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,004%
2 E 1 Semiconductors	c-C4F8	0,00	0,23		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 E 1 Semiconductors	SF6	0,00	6,61		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,005%
2 E 1 Semiconductors	NF3	0,00	0,71		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 E 4 Heat transfer fluid	HFC-32	0,00	0,00		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 E 4 Heat transfer fluid	HFC-125	0,00	0,00		100%	100%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,000%
2 F 1 a Commercial refrigeration	HFC-32	0,00	62,96		75%	75%	0,0000%	0,000%	0,000%	0,03%	0,00%	0,032%
2 F 1 a Commercial refrigeration	HFC-125	4,03	910,19		75%	75%	0,0034%	0,006%	0,006%	0,46%	0,00%	0,465%
2 F 1 a Commercial refrigeration	HFC-134a	64,91	346,70		75%	75%	0,0005%	0,002%	0,002%	0,15%	0,00%	0,151%
2 F 1 a Commercial refrigeration	HFC-143a	6,03	777,58		75%	75%	0,0025%	0,005%	0,005%	0,40%	0,00%	0,396%
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	1,79		75%	75%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2 F 1 b Domestic refrigeration	HFC-134a	0,05	1,25		75%	75%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,001%
2 F 1 d Transport refrigeration	HFC-32	0,00	0,32	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	11,62	100%	50%	115%	0,0000%	0,000%	0,000%	0,00%	0,01%	0,012%
2 F 1 d Transport refrigeration	HFC-134a	0,12	3,00	100%	50%	115%	0,0000%	0,000%	0,000%	0,00%	0,00%	0,003%
2 F 1 d Transport refrigeration	HFC-143a	0,86	15,03	100%	50%	95	115%	0,0000%	0,000%	0,000%	0,01%	0,015%

Table 3.2 : Approach 1 uncertainty calculation and reporting for the year 2016 - 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)	2016 emissions	Activity data uncertainty (%)	Emission factor uncertainty (%)	Combined uncertainty	Contribution to Variance by Category in 2016	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										
		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 F 1 e Mobile air-conditioning	HFC-32	0,00	0,05	100%	50%	115%	0,0000%	0,0000%	0,0000%	0,00%	0,00%	0,0000%
2 F 1 e Mobile air-conditioning	HFC-125	0,00	0,27	100%	50%	115%	0,0000%	0,0000%	0,0000%	0,00%	0,00%	0,0000%
2 F 1 e Mobile air-conditioning	HFC-134a	26,59	609,46	100%	50%	115%	0,0035%	0,004%	0,004%	0,20%	0,59%	0,623%
2 F 2 a Closed cell foam	HFC-134a	356,73	61,66	15%	5%	16%	0,0000%	-0,002%	0,0000%	-0,01%	0,01%	0,012%
2 F 2 a Closed cell foam	HFC-152a	0,06	17,85	15%	5%	16%	0,0000%	0,0000%	0,0000%	0,00%	0,00%	0,003%
2 F 2 a Closed cell foam	HFC-227ea	0,00	4,32	15%	5%	16%	0,0000%	0,0000%	0,0000%	0,00%	0,00%	0,001%
2 F 2 a Closed cell foam	HFC-245fa	0,01	0,73	15%	5%	16%	0,0000%	0,0000%	0,0000%	0,00%	0,00%	0,000%
2 F 2 a Closed cell foam	HFC-365mfc	0,00	7,55	15%	5%	16%	0,0000%	0,0000%	0,0000%	0,00%	0,00%	0,001%
2 F 3 Fire protection	HFC-125	0,00	0,90	10%	50%	51%	0,0000%	0,0000%	0,0000%	0,00%	0,00%	0,0000%
2 F 3 Fire protection	HFC-227ea	0,58	11,97	10%	50%	51%	0,0000%	0,0000%	0,0000%	0,00%	0,00%	0,004%
2 F 4 a Metered dose inhalers	HFC-134a	0,00	48,52	25%	50%	56%	0,0000%	0,0000%	0,0000%	0,02%	0,01%	0,020%
2 F 4 a Metered dose inhalers	HFC-227ea	0,00	0,57	25%	50%	56%	0,0000%	0,0000%	0,0000%	0,00%	0,00%	0,000%
2 F 4 b Technical aerosols	HFC-134a	41,41	42,01		200%	200%	0,0001%	0,0000%	0,0000%	0,01%	0,00%	0,012%
2 F 4 b Technical aerosols	HFC-152a	0,04	0,32		200%	200%	0,0000%	0,0000%	0,0000%	0,00%	0,00%	0,000%
2 G 1 Electrical equipment	SF6	7,75	10,62		50%	50%	0,0000%	0,0000%	0,0000%	0,00%	0,00%	0,002%
2 G 2 c Soundproof windows	SF6	79,77	77,43		100%	100%	0,0000%	0,0000%	0,001%	0,01%	0,00%	0,009%
2 G 2 d Adiabatic properties: shoes	SF6	46,93	0,00		100%	100%	0,0000%	0,0000%	0,0000%	-0,03%	0,00%	0,026%
2 G 2 e Laboratory uses	C6F14	0,00	0,00		100%	100%	0,0000%	0,0000%	0,0000%	0,00%	0,00%	0,0000%
Total F-gases		5 556,02	3 693,10				0,0101%					0,008%
Total 7 GHGs (without LUCF)		146 294,18	117 443,26 (2015)			Percentage uncertainty in total inventory	1,004%			Trend uncertainty		0,892%

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.

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

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

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10 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 25: 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
CCl ₄	Other ODS	ODS	-380	AR5	1,1
CH ₃ Br	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 26: List of emission sources with their allocation to the CRF source categories

Name of Worksheet	CRF Code	CRF source category
01. Dom. refrig. - Coolant	2 F 1 b	Domestic refrigeration
02. Dom. refrig. - Foam	2 F 2 a	Closed cell foam
03. RAC & heat pumps	2 F 1 a	Commercial refrigeration
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 27: Nomenclature of the CRF format

CRF Code	CRF source category	Aggregated source
2 B	Chemical industry	
2 B 9	Fluorocarbon 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