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Administration de l'environnement

Luxembourg's National Inventory Report 1990-2015

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Project management

Dr Marc Schuman – Environment Agency

Authors

Tom Bechet - Water Management Administration

Nora Becker - Environment Agency

Eric De Brabanter – Ministry of Sustainable Development and Infrastructures

Pierre Dornseiffer – Environment Agency

Kirsten Franz – SEG Umwelt-Service GmbH

Ermin Hadzic – Environment Agency

Jean-Paul Hoffmann – Rural Economics Service (Ministry of Agriculture)

Martine Kemmer - Environment Agency

Dominique Manetta – Water Management Administration

Tim Mirgain – Environment Agency

Isabelle Naegelen – Environment Agency

Jim Ruppert – Rural Economics Service (Ministry of Agriculture)

Marc Schuman – Environment Agency

with the help of Umweltbundesamt (UBA) Austria: Traute Köther and Peter Weiss

and contributions from:

Willibald Croi - Luxspace Sàrl

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Questions and comments should be addressed to:

Administration de l’environnement

Unité Surveillance et évaluation de l’environnement

1, avenue du Rock'n'Roll

L - 4361 Esch-sur-Alzette

emission.inventory@aev.etat.lu

Index of Tables

Index of Figures

Executive Summary

ES.1. Background information on greenhouse gas (GHG) inventories and climate change

ES.1.1. Background information on climate change

Climate as such is the totality of all atmospheric conditions at a particular location. It undergoes natural variability. Since industrialisation started some 150 years ago, mankind has been influencing the climate via the emission of greenhouse gases. In 1994, by setting up the United Nations Framework Convention on Climate Change (UNFCCC), the nations of the world came together to start a process to prevent dangerous effects of climate change. However, the Convention did not include binding commitments. To go this step further, the Kyoto Protocol was adopted in 1997 and sets binding targets for 37 industrialized countries for the period 2008-2012. The so called Doha Agreement extends the Kyoto Protocol until 2020, however it has not yet been set into force.

ES.1.2. Background information on greenhouse gas (GHG) inventories

In order to evaluate the trend of greenhouse gas emissions and the progress in achieving the reduction target, it is necessary to regularly compile an emissions inventory. The compilation of these inventories follows rules as set up by the UNFCCC and the Kyoto Protocol.

ES.2. Summary of National Emission and Removal related Trends

ES.2.1. Greenhouse Gas (GHG) Inventory

In 2015, Luxembourg's greenhouse gas emissions amounted to a total of 10.267 million tonnes calculated in CO_2 equivalents (*CO_2e*) – excluding land-use, land-use change and forestry (*LULUCF*). Carbon dioxide (*CO_2*) was the main source of greenhouse gases (GHG) in Luxembourg (Table 0-1). This source counted for 90.10% of the total GHG emissions (excluding LULUCF). The second source of GHG was methane (*CH_4*) with about 6.30% of the total emissions excluding LULUCF. Nitrous oxide (*N_2O*) was the third source with 2.83%. Fluorinated gases (*F-gases*) only accounted for 0.77% of the total emissions excluding LULUCF, with hydrofluorocarbons (*HFCs*) representing 0.68%, and sulphur hexafluoride (*SF_6*) representing 0.09% of the national total (excl. LULUCF).

In 2015, total GHG emissions decreased by 4.53% compared to 2014 and 19.34% below their base year level [1]. For the different GHG, trends over the period 1990-2015 (and 2014-2015) were as follows:

- CO_2: .... -21.22% (-5.01%)
- CH_4: .... -2.12% (+1.08%)
- N_2O: .... -6.02% (-1.05%)
- F-gases: .... +285.46%[2] (+0.47%)

Carbon dioxide emissions, over the period 1990-2015, are characterised by a V-shape evolution driven by changes in the sources of emissions: declining emissions in industry due to technological changes in the iron and steel production, increasing emissions from transport and natural gas fired power plants. The last emission peak was attained in 2005 and, since then, the emissions seem to be continuously decreasing until 2009. This decrease was interrupted in 2010, where emissions increased by 5.0% compared to 2009. However, since 2005 emissions have decreased by 20.8%.

Methane emissions have declined over the period due to the reduced methane emissions in waste management (-24.9%) and increasing emissions in agriculture (+1.6%) and in energy use (+9.6%), the latter being due to an upward trend for fugitive emissions from natural gas distribution and use, and to a lesser extent in energy production industries and in the commercial and residential sector.

Nitrous oxide emissions development is closely linked to an increase of liquid fuels related emissions from combustion activities and the waste sector that could not be balanced by declining emissions from the agriculture and solvent and other product use sectors.

With regard to F-gases, HFCs emissions increased by 285% in 2015 compared to the base year (1995), whereas SF_6 emissions showed an 9-fold increase between 1995 and 2015.

Finally, when including emissions and removals from land use, land use change and forestry (LULUCF), Luxembourg's greenhouse gas emissions amounted to a total of 9.862 million tonnes CO_2 eq (incl. LULUCF). Net removals from the LULUCF sector amounted to 404.9 Gg CO_2 eq. Since 1990, net emissions have decreased by 938% per cent (the sector was a source of net emissions in 1990 (48.33 Gg CO_2 eq) and a source of net removals in 2015).

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1 The base year for CO_2, CH_4 and N_2O is 1990. For the F-gases, the base year is 1995.

2 The trend indicated here corresponds to the period 1995 to 2014, as dthe base year for F-gases is 1995.

ES.2.2. KP-LULUCF activities

In 2015, Article 3.3 activities were a net sink in Luxembourg and net CO_2 removals amounted to 130.73 Gg CO_2e. Removals from afforestation/reforestation amounted to 173.19 Gg CO_2. About 2/3 of these gains were caused by the C stock increases in living biomass, 1/3 was due to increases in soil carbon and litter at the aforestation/reforestation (*AR*) areas. In the same year, emissions from deforestation amounted to 42.46 Gg CO_2. About 1/3 were due to biomass losses, and 2/3 due to C stock losses in litter and soil.

Under Article 3.4, the activity forest management has now been included. CO_2 removals amounted to 306.5 Gg CO_2e. By taking into account the FMRL of 418 Gg CO_2e and a technical correction of 181,68 Gg CO_2e, the activity forest management becomes a net removal of 70.15 Gg CO_2e. Due to a lack of reliable data, emissions or sinks due to HWP could not be estimated.

ES.3. Overview of Source and Sink Category Emission Estimates and Trends

ES.3.1. Greenhouse Gas Inventory

Table 0-2 splits up total GHG emissions of Luxembourg for the five CRF sectors to be included in the inventory. In 2015, the energy sector accounted for almost 89.94% of the total GHG emissions, excluding LULUCF. Two sectors represented between 6% and 7% of the total emissions, excluding LULUCF: industrial processes and product use (6.35%) and agriculture (6.90%). The remaining sectors[3] (LULUCF (4.10%), waste[4] (0.88%) and other (NA)) were not even reaching over 5.0% of the total GHG emitted in Luxembourg.

For the different sectors, trends over the period 1990-2015 (and 2014-2015) were as follows:

- Energy: .... -13.59% (-5.24%)
- Industrial processes & product use: .. -61.83% (-1.10%)
- Agriculture: .... -4.70% (+2.15%)
- LULUCF:... -937.79% (-11.24%)
- Waste: .... -16.94% (-3.85%)
- Other: .... NA

3 The sector "other" is not reported for Luxembourg.

4 The waste sector covers only landfilled waste, wastewater handling and composting activities. Waste incineration, which is the main treatment method for municipal waste in Luxembourg, is carried out in the sole incinerator of the country where energy is recovered. Consequently, waste incineration related emissions are accounted for in CRF sector 1 – Energy (details in Chapters 3 and 8 respectively).

Emission reductions observed in all sectors could just balance the growth of **energy use and production** related emissions whose contribution to total GHG emissions, excluding LULUCF, ranged from 80% to 90% over the period 1990 to 2015. Within the energy sector, the fastest growing sub-sectors were energy industries (1A1) (due to the operational start of the Twinerg gas turbine in 2001) and transportation (1A3): +1183% and +120%, respectively between 1990 and 2015 -31.61% and -6.69% from 2014 to 2015) with, as a result, a share in the total energy related GHG emissions rising from 0.28% to 4.64% and 20.2% to 57.7%, respectively. For the other sub-sectors, the observed trends between 1990 and 2015 are -82.2% for manufacturing industries (1A2), +15.7% for the other sectors (1A4), and +78.5% for fugitive emissions from fuels (1B).[5]

Trends in **agriculture**, which was the second largest sector in 2014 in terms of GHG emissions, were also favourable between 1990 and 2015: declining GHG emissions were observed for agricultural soils (-22.6%) and enteric fermentation by (-1.0%), whereas liming increased by 885% and manure management by 9.0%.

The third largest sector in Luxembourg with regard to 2015 GHG emissions, *i.e.* **industrial processes and product use**, shows a declining trend between 1990 and 1998, then a relative stabilisation. This evolution was mainly driven by process changes that occurred in the steel industry (recorded under 2C1), which moved from blast to electric arc furnaces between 1994 and 1998. As a consequence, GHG emissions of the iron and steel industry decreased by 88% since 1990. Compared to 2014, emissions from industrial processes and product use decreased by 1,1% in 2015, which is mainly due to a decrease in the category *2.A.- Mineral Industry*.

In the **waste** sector, the main source of GHG was solid waste disposal on land (5A), but its weight decreased over the period 1990-2015 due to the combination of reduced amounts of landfilled waste and increased emissions arising from composting activities (5D). GHG emission reduction for solid waste disposal on land (-44.5% between 1990 and 2015) still drove a reduction for the overall waste sector despite rising emissions from composting. Wastewater handling emissions (5B) decreased by 34.5% over the same period.

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From this analysis, it is obvious that the biggest challenge Luxembourg is facing, with regard to GHG emissions reduction, is to limit emissions from the energy sector, and more particularly from the transportation sector. Detailed explanations on the very high shares of CO_2 from the energy sector will be provided in Chapter 2, when analysing trends in Luxembourg's GHG emissions. Also, specific national circumstances are to be kept in mind when appreciating GHG emissions trends and composition in Luxembourg. These circumstances will be exposed in Chapter 2 as well.

5 Fugitive emission growth is closely linked to natural gas use in Luxembourg.

ES.3.2. KP-LULUCF activities

In 2015, Article 3.3 activities were a net sink in Luxembourg and net CO_2 removals amounted to 130.73 Gg CO_2e. CO_2 removals from Aforestation/Reforestation (AR) in Luxembourg amounted to 173.19 Gg CO_2. 123.67 Gg CO_2 resulted from an increase in above-and belowground biomass, 4.78 Gg CO_2 from dead wood, 16.33 Gg CO_2 from litter and 28.41 Gg CO_2 from soil carbon. Emissions from Deforestation (D) activities were approximately 42.46 Gg CO_2e in 2015. 17.01 Gg CO_2 resulted from a loss in above- and belowground biomass, 0.81 Gg CO_2 from dead wood, 2.77 Gg CO_2 from litter and 19.35 Gg CO_2 from soil carbon. N_2O emissions from disturbance associated with land use conversion amounted to 2.52 Gg CO_2e.

Under Article 3.4, Luxembourg is reporting removals of 70.15 Gg CO_2e in the year 2015. This corresponds to a 57% decrease compared to the figures from 2014, where the activity of forest management was also a net sink. This decrease in CO_2 removals can be solely attributed to an increase of wood harvested in 2015.

ES.4. Other information: Emission Estimates and Trends of Indirect GHG and SO_2

Some indirect GHG – NO_x, CO, NMVOCs – and SO_2 emissions are recorded and reported in the inventory. The emissions of these air pollutants are estimated and reported under the UNECE Convention on Long-Range Transboundary Air Pollution (*CLRTAP*). For more details on the emissions of these pollutants please refer to Luxembourg's Air Pollutant Emission Inventory and its releted Informative Inventory report, which are both published on the Center on Emission Inventories and Projections website:

http://www.ceip.at/ms/ceip_home1/ceip_home/status_reporting

Table 0-1 – Luxembourg's GHG emissions and removals (excl. LULUCF) – overview by main gases: 1990-2015

Gg (1000 t.) CO_2 eq	1990 (base year)	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
CO_2	11812.05	12428.21	12188.83	12327.93	11516.20	9124.44	9171.13	8523.01	7639.44	8090.96	8673.16	9166.12	9942.38
	92.79%	*92.98%*	*92.90%*	*93.00%*	*92.72%*	*90.79%*	*90.73%*	*90.08%*	*89.05%*	*89.50%*	*90.19%*	*90.73%*	*91.37%*
CH_4 (1)	634.97	641.56	630.76	629.56	605.20	620.68	630.29	631.08	628.50	633.85	626.10	630.97	630.42
	4.99%	*4.80%*	*4.81%*	*4.75%*	*4.87%*	*6.18%*	*6.24%*	*6.67%*	*7.33%*	*7.01%*	*6.51%*	*6.25%*	*5.79%*
N_2O (2)	282.56	295.94	285.82	282.57	281.17	285.11	285.31	282.91	283.90	286.56	286.21	269.79	269.45
	2.22%	*2.21%*	*2.18%*	*2.13%*	*2.26%*	*2.84%*	*2.82%*	*2.99%*	*3.31%*	*3.17%*	*2.98%*	*2.67%*	*2.48%*
HFCs (3)	0.00	0.00	13.68	14.70	15.98	18.31	20.06	22.54	24.98	26.78	29.58	33.49	36.38
	0.00%	*0.00%*	*0.10%*	*0.11%*	*0.13%*	*0.18%*	*0.20%*	*0.24%*	*0.29%*	*0.30%*	*0.31%*	*0.33%*	*0.33%*
PFCs (3)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	NA	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
SF_6 (3)	0.88	0.98	1.08	1.19	1.30	1.39	1.56	1.70	1.74	1.83	1.93	2.54	3.15
	0.01%	*0.01%*	*0.01%*	*0.01%*	*0.01%*	*0.01%*	*0.02%*	*0.02%*	*0.02%*	*0.02%*	*0.02%*	*0.03%*	*0.03%*
Total GHG excluding LULUCF	**12730.46**	**13366.69**	**13120.17**	**13255.94**	**12419.85**	**10049.92**	**10108.35**	**9461.25**	**8578.56**	**9039.99**	**9616.97**	**10102.92**	**10881.78**
	100.00%	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*

Gg (1000 t.) CO_2 eq	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
CO_2	10411.66	11785.51	12044.64	11882.64	11290.95	11155.91	10616.84	11184.97	11088.43	10816.35	10266.72	9797.16	9305.96
	91.94%	*92.67%*	*92.93%*	*92.85%*	*92.36%*	*92.11%*	*91.74%*	*92.06%*	*92.08%*	*92.06%*	*91.56%*	*91.09%*	*90.62%*
CH_4 (1)	618.77	614.43	612.34	609.15	620.07	631.34	632.38	633.18	608.81	598.19	602.96	614.86	621.50
	5.46%	*4.83%*	*4.72%*	*4.76%*	*5.07%*	*5.21%*	*5.46%*	*5.21%*	*5.06%*	*5.09%*	*5.38%*	*5.72%*	*6.05%*
N_2O (2)	251.46	272.16	259.54	258.21	261.26	268.70	266.50	271.49	281.56	268.89	273.54	268.39	265.56
	2.22%	*2.14%*	*2.00%*	*2.02%*	*2.14%*	*2.22%*	*2.30%*	*2.23%*	*2.34%*	*2.29%*	*2.44%*	*2.50%*	*2.59%*
HFCs (3)	38.70	40.78	39.79	42.77	47.37	49.77	51.16	53.46	56.34	58.73	62.36	67.12	67.03
	0.34%	*0.32%*	*0.31%*	*0.33%*	*0.39%*	*0.41%*	*0.44%*	*0.44%*	*0.47%*	*0.50%*	*0.56%*	*0.62%*	*0.65%*
PFCs (3)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	NA	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
SF_6 (3)	3.73	4.28	4.85	5.27	5.69	6.10	6.49	6.87	7.31	7.68	8.05	8.44	8.89
	0.03%	*0.03%*	*0.04%*	*0.04%*	*0.05%*	*0.05%*	*0.06%*	*0.06%*	*0.06%*	*0.07%*	*0.07%*	*0.08%*	*0.09%*
Total GHG excluding LULUCF	**11324.32**	**12717.16**	**12961.17**	**12798.04**	**12225.34**	**12111.83**	**11573.37**	**12149.97**	**12042.45**	**11749.85**	**11213.64**	**10755.97**	**10268.93**
	100.00%	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*

Source: Environment Agency
Notes:
(1) The methane emissions are converted in CO_2 equivalents by multiplying the emissions by 25, i.e. the global warming potential (GWP) value for methane based on the effects of GHG over a 100-year time horizon.
(2) The nitrous oxide emissions are converted in CO_2 equivalents by multiplying the emissions by 298, i.e. the global warming potential (GWP) value for nitrous oxide based on the effects of GHG over a 100-year time horizon.
(3) The F-gases are those not covered by the Montreal Protocol, i.e. HFCs, PFCs and SF_6 expressed in CO_2 equivalents using the global warming potential (GWP) values based on the effects of GHG over a 100-year time horizon.

Table 0-2 – Luxembourg's GHG emissions and removals – overview by main CRF Sectors: 1990-2015

Gg (1000 t.) CO_2 eq	1990 (base year)	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
1. Energy	10263.87	10966.43	10801.12	10965.53	10247.29	8214.19	8319.54	7780.67	7055.50	7472.60	8030.26	8584.48	9355.53
	80.62%	*82.04%*	*82.32%*	*82.72%*	*82.51%*	*81.73%*	*82.30%*	*82.24%*	*82.25%*	*82.66%*	*83.50%*	*84.97%*	*85.97%*
2. Industrial Processes	1640.25	1561.67	1503.97	1481.51	1389.81	1031.71	977.24	869.97	711.96	750.89	779.35	725.92	746.81
	12.88%	*11.68%*	*11.46%*	*11.18%*	*11.19%*	*10.27%*	*9.67%*	*9.20%*	*8.30%*	*8.31%*	*8.10%*	*7.19%*	*6.86%*
3. Agriculture	714.41	724.90	701.13	694.30	676.37	697.77	704.09	700.39	698.93	704.84	695.38	681.24	667.34
	5.61%	*5.42%*	*5.34%*	*5.24%*	*5.45%*	*6.94%*	*6.97%*	*7.40%*	*8.15%*	*7.80%*	*7.23%*	*6.74%*	*6.13%*
4. Land use, land-use change and forestry	44.42	-232.82	-562.00	-657.06	-467.88	-570.96	-611.38	-694.11	-578.53	-676.24	-705.87	-717.51	-718.84
	0.35%	*-1.74%*	*-4.28%*	*-4.96%*	*-3.77%*	*-5.68%*	*-6.05%*	*-7.34%*	*-6.74%*	*-7.48%*	*-7.34%*	*-7.10%*	*-6.61%*
5. Waste	111.92	113.69	113.95	114.60	106.38	106.25	107.48	110.21	112.16	111.66	111.98	111.29	112.10
	NA	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
6. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	0.00%	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
Total GHG including LULUCF	**12774.88**	**13133.86**	**12558.17**	**12598.88**	**11951.97**	**9478.97**	**9496.97**	**8767.14**	**8000.02**	**8363.75**	**8911.10**	**9385.41**	**10162.93**
	100.00%	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*
Total GHG excluding LULUCF	**12730.46**	**13366.69**	**13120.17**	**13255.94**	**12419.85**	**10049.92**	**10108.35**	**9461.25**	**8578.56**	**9039.99**	**9616.97**	**10102.92**	**10881.78**
	100.00%	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*

Gg (1000 t.) CO_2 eq	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1. Energy	9880.33	11203.15	11487.42	11277.84	10693.98	10618.52	10148.88	10703.60	10588.26	10379.26	9842.25	9359.67	8869.05
	87.25%	*88.09%*	*88.63%*	*88.12%*	*87.47%*	*87.67%*	*87.69%*	*88.10%*	*87.92%*	*88.34%*	*87.77%*	*87.02%*	*86.37%*
2. Industrial Processes	694.04	754.04	725.49	779.76	775.92	721.51	651.30	675.52	692.17	632.90	616.96	633.08	626.08
	6.13%	*5.93%*	*5.60%*	*6.09%*	*6.35%*	*5.96%*	*5.63%*	*5.56%*	*5.75%*	*5.39%*	*5.50%*	*5.89%*	*6.10%*
3. Agriculture	633.59	647.20	635.84	627.26	641.42	655.35	658.86	668.17	662.00	642.50	658.25	666.53	680.83
	5.59%	*5.09%*	*4.91%*	*4.90%*	*5.25%*	*5.41%*	*5.69%*	*5.50%*	*5.50%*	*5.47%*	*5.87%*	*6.20%*	*6.63%*
4. Land use, land-use change and forestry	-681.42	-685.12	-639.48	-557.35	-477.38	-493.94	-471.09	-155.93	-277.84	-363.44	-538.64	-458.83	-407.41
	-6.02%	*-5.39%*	*-4.93%*	*-4.35%*	*-3.90%*	*-4.08%*	*-4.07%*	*-1.28%*	*-2.31%*	*-3.09%*	*-4.80%*	*-4.27%*	*-3.97%*
5. Waste	116.36	112.77	112.43	113.17	114.02	116.45	114.33	102.68	100.02	95.19	96.18	96.69	92.97
	NA	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
6. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	0.00%	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
Total GHG including LULUCF	**10642.91**	**12032.04**	**12321.70**	**12240.69**	**11747.96**	**11617.88**	**11102.28**	**11994.04**	**11764.60**	**11386.41**	**10674.99**	**10297.13**	**9861.53**
	100.00%	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*
Total GHG excluding LULUCF	**11324.32**	**12717.16**	**12961.17**	**12798.04**	**12225.34**	**12111.83**	**11573.37**	**12149.97**	**12042.45**	**11749.85**	**11213.64**	**10755.97**	**10268.93**
	100.00%	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*

Source: Environment Agency
Notes: Percentages are relative to the total GHG emissions excluding LULUCF.

1 Introduction

1.1 Background information on greenhouse gas inventories and climate change

1.1.1 Background information on climate change

1.1.1.1 Global Warming

Global warming is the increase in the average temperature of Earth's near-surface air and oceans since the mid-20th century and its projected continuation. Global surface temperature increased 0.74 ± 0.18 °C between the start and the end of the 20th century[6] . The Intergovernmental Panel on Climate Change (IPCC) concludes that most of the observed temperature increases since the middle of the 20th century was very likely caused by increasing concentrations of greenhouse gases resulting from human activity such as fossil fuel burning and deforestation. The IPCC also concludes that variations in natural phenomena such as solar radiation and volcanic eruptions had a small cooling effect after 1950.

Climate model projections summarized in the latest IPCC report indicate that the global surface temperature is likely to rise a further 1.1 to 6.4 °C during the 21st century. The uncertainty on this estimate arises from the use of models with differing sensitivity to greenhouse gas concentrations and the use of differing estimates of future greenhouse gas emissions. Most studies focus on the period leading up to the year 2100. However, warming is expected to continue beyond 2100 even if emissions stop, because of the large heat capacity of the oceans and the long lifetime of carbon dioxide in the atmosphere.

An increase in global temperature will cause sea levels to rise and will change the amount and pattern of precipitation, probably including expansion of subtropical deserts. Warming is expected to be strongest in the Arctic and would be associated with continuing retreat of glaciers, permafrost and sea ice. Other likely effects include changes in the frequency and intensity of extreme weather events, species extinctions, and changes in agricultural yields. Warming and related changes will vary from region to region around the globe, though the nature of these regional variations is uncertain.

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6 IPCC (2007-05-04), "Summary for Policymakers" (PDF). Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. http://www.ipcc-wg1.unibe.ch/publications/wg1-ar4/wg1-ar4-spm.pdf. Retrieved 2010-03-23.

1.1.1.2 Climate Change in Luxembourg

Annual mean temperatures for Luxembourg-City are nowadays usually above the 30 years averages of the last century. Indeed, the 1951-1980, the 1961-1990 or the 1971-2000 mean yearly temperatures for the capital city – around 9°C – are nowadays regularly exceeded: since the turn of the 21st century, annual mean temperatures are comprised between 9.3°C (2001) and 11.3°C (2007), 9.9°C in 2016. The variation of yearly averages is mainly driven by variations in air temperatures during winter seasons. Other meteorological stations disseminated throughout the country show similar results. With regard to other meteorological parameters – rainfalls, sunshine hours, relative humidity – no clear trends can be identified yet, probably because the very small size of the country (2 586 km^2) limits the identification of such changes.

Climate change effects are also witnessed by increasing frost-free periods, earlier blooming seasons and higher flood frequencies over the last 20 years. For the future, higher average yearly temperatures are anticipated with consequences on public health (heat waves), floods (higher frequency and intensity), vegetation cycles (longer periods with frost risks after early blooming) and forests (degradation of its phytosanitary state).

More details are provided in Section 2.1.2 of this NIR.

1.1.1.3 The Convention, the Kyoto Protocol and its flexible mechanisms

In 1992, Luxembourg signed the United Nations Framework Convention on Climate Change (UNFCCC) which sets an ultimate objective of stabilizing atmospheric concentrations of greenhouse gases at levels that would prevent "dangerous" human interference with the climate system. Such levels, which the Convention does not quantify, should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

The UNFCCC covers all greenhouse gases not covered by the Montreal protocol: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) as well as hydrogenated fluorocarbons (HFCs), perfluorated halocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3).

Five years after adoption of the Climate Change Convention in 1997, governments took a further step forward and adopted the Kyoto Protocol (KP). Building on the Convention, the Kyoto Protocol sets out legally binding constraints on greenhouse gas emissions and "mechanisms" aimed at cutting the cost of curbing emissions. Under the terms of the Protocol, the industrialised parties – known as Annex 1 countries – pledged to reduce their greenhouse gas (GHG) emissions by 5% below the 1990 levels by the period 2008–2012. The European Union is also a Party to the Convention and the KP and agreed on a reduction target of 8% below 1990 levels during the five-year commitment period from 2008 to 2012. The EU and its Member States decided to achieve this goal jointly, for Luxembourg an emission target of minus 28% was set.

During an extensive review process in 2007, the so called Pre-commitment period review, the percentual reduction commitments of the Annex 1 countries were converted and fixed to absolute emission values, the so called assigned amounts.

Luxembourg signed the KP on 29th April 1998, and ratified the protocol on 31st May 2002. The KP entered into force on 16 February 2005, triggered by Russia's ratification in November 2004 which fulfilled the requirement that at least 55 Parties to the Convention ratified the Protocol.

The Protocol sets out three 'flexible mechanisms' to help countries meet their obligations to cut emissions.

- *Emission Trading*: Article 17 of the Kyoto Protocol allows Annex I Parties (basically, the industrialised nations) to purchase the rights to emit GHG from other Annex I countries which have reduced their GHG emissions below their assigned amounts. Trading can be carried out by intergovernmental emission trading, or entity-source trading where assigned amounts are allocated to sub-national entities.
- *Joint Implementation*: Article 6 allows an Annex I Party to gain a credit (converted to As-signed Amounts) by investing in another Annex I country in a project which reduces GHG emissions.
- *Clean Development Mechanism*: Article 12 allows an Annex I country (or companies in an Annex 1 country) which funds projects in developing countries (non-Annex I Party) to get credits for certified emission reductions providing that "benefits" accrue for the host country.

Tradable emission permits tie the emissions to a fixed ceiling, the costs of emission reduction being as low as possible.

The final assessment on compliance with the goals of the first commitment period of the KP will be made in the true up process after finalization of the last review reports in 2015.

The so called Doha Agreement extends the Kyoto Protocol until 2020, establishing a second commitment period. However, it has not yet been set into force as by the end of 2014 only 23 Parties have deposited their instruments of acceptance (144 are needed).

Independently of the setting into force of the Doha Agreement, the European Community has fixed its goal in the so called Effort Sharing Decision (Decision No 406/2009/EC of the European Parliament and of the Council of 23 April 2009 on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020), with the goal of a 20% cut of emissions below the 1990 emission level by

2020. The ESD Directive also sets national emission targets for the member states, Luxembourg's target is −20% related to 2005 (not considering the sectors/sources regulated by the EU ETS).

1.1.2 Background information on greenhouse gas inventories

As a Party to the UNFCCC, Luxembourg is required to produce and regularly update national greenhouse gas emission inventory. To date, GHG inventories have been produced for the years 1990 to 2014. Furthermore Parties shall submit a National Inventory Report (NIR) containing detailed and complete information on their inventories, in order to ensure the transparencyof the inventory.

Responsible for the preparation of Luxembourg's National Greenhouse Gas Inventory as well as the preparation of the NIR is the *Unité surveillance et évaluation de l'environnement* of the Environment Agency, under the political responsibility of the Ministry of Sustainable Development and Infrastructures.

The present NIR documents Luxembourg's GHG emission inventory in accordance with the updated UNFCCC reporting guidelines on annual inventories. It is aimed at complying with decisions 11/CP.4, 3/CP.5, 18/CP.8, 14/CP.11, 15/CP.17 and 24/CP.19 of the COP and with European Parliament and Council Decision 280/2004/EC as amended by Regulation 525/2013 concerning a mechanism for monitoring Community GHG emissions and for implementing the Kyoto Protocol. It includes a description of the methodologies and data sources used for estimating emissions by sources and removals by sinks, a discussion of these estimates and their trends (including an analysis of the key source categories), and information on recalculation, uncertainties, quality assessment and quality control.

This report is an update of the previous NIR submitted in 2016.[7] It is based on data submitted to the UNFCCC in the Common Reporting Format (*CRF*) on 15th April 2017: submission 2017v1.2.[8] Besides being a submission under the UNFCCC, submission 2017v1.2 is also a mandatory submission under the Kyoto Protocol.

The structure of this NIR follows, as much as possible, the outlines as set out in the updated UNFCCC reporting guidelines on annual inventories following incorporation of the provisions of

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7 Luxembourg's National Inventory Report dated 15 April 2016 (covering inventory years 1990 to 2014)

8 Submission 2017v1.2 can be downloaded from:
a) The Central Data Repository of the European Environment Information and Observation Network (EIONET) of the European Environment Agency (EEA): http://cdr.eionet.europa.eu/lu/eu/mmr/art07_inventory/ghg_inventory;
b) The UNFCCC web site: http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/10116.php.

decision 24/CP.19 (see document FCCC/CP/2013/10/Add.3)[9], as well as the annotated outline of the NIR that can be found on the UNFCCC website.[10]

This report was compiled by Dr Marc Schuman (Environment Agency) with the help of Dr Nora Becker (Environment Agency) and Traute Köther (Umweltbundesamt, Vienna). Specific responsibilities for this 2017 NIR have been as follows:

Executive Summary:	Marc Schuman
Chapter 1:	Marc Schuman, Nora Becker (key category analysis & uncertainties), and Kirsten Franz (QA/QC)
Chapter 2:	Tim Mirgain, Isabelle Naegelen, Marc Schuman
Chapter 3:	Marc Schuman, Nora Becker
Chapter 4:	Ermin Hadzic, Pierre Dornseiffer
Chapter 5:	Jim Ruppert, Jean-Paul Hoffmann
Chapter 6:	Tim Mirgain with the help of Georges Kugener, Willibald Croi and Peter Weiss (UBA Vienna);
Chapter 7:	Isabelle Naegelen, Yves Jacoby, Dominique Manetta, Tom Bechet
Chapters 8 & 9:	Marc Schuman
Chapter 10:	Marc Schuman, Nora Becker
Chapter 11:	Tim Mirgain with the help of Willibald Croi and Peter Weiss (UBA Vienna);
Chapter 12:	Martine Kemmer, Nora Becker, Tim Mirgain
Chapter 13:	Marc Schuman
Chapter 14:	Martine Kemmer, Nora Becker
Chapter 15 & 16:	Marc Schuman

The GHG inventory reviewed in the present NIR covers the period 1990-2015 and contains information on anthropogenic emissions by sources and removals by sinks for direct GHG (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6 and NF_3). With regard to indirect greenhouse gases (CO, NO_x, NMVOCs) and SO_2, though also recorded in this inventory, they are derived from the air pollutant

9 http://unfccc.int/resource/docs/2006/sbsta/eng/09.pdf

10 Annotated outline of the National Inventory Report including reporting elements under the Kyoto Protocol: http://unfccc.int/files/national_reports/annex_i_ghg_inventories/reporting_requirements/application/pdf/annotated_nir_outline.pdf

emission inventory Luxembourg is compiling for the United Nations Economic Comission for Europe's Convention on Long-Range Transboundary Air Pollution (UN-ECE CLRTAP). Consequently, indirect GHG and SO_2 emissions are not discussed in this NIR. For more details on the emissions of these pollutants please refer to Luxembourg's Air Pollutant Emission Inventory and its releted Informative Inventory report, which are both published on the Center on Emission Inventories and Projections website[11].

1.1.3 Background information on supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol

Besides the information that Parties to the Convention have to report annually, Parties to the Kyoto Protocol are additionally required to report supplementary information necessary to determine compliance with the regulations of the Protocol. This information is generally referred to as "supplementary information under Article 7, paragraph 1 of the Kyoto Protocol". Main elements of this information are the reporting on Kyoto Protocol 3.3 and 3.4 activities and reporting on national registries and Kyoto Protocol units:

1.1.3.1 Article 3.3 and 3.4 activities

Luxembourg reports only the mandatory Art. 3.3 and Art. 3.4 activities. They include emissions/removals from human-induced Aforestation/Reforestation/Deforestation activities since 1990 (Art. 3.3) and forest management (Art. 3.4). In addition, Parties may elect to include emissions/removals from any of the following human-induced activities since 1990 (Art. 3.4): Cropland management, Grazing land management and Revegetation. Luxembourg has not elected Article 3.4 activities such as Cropland management, Grazing land management and Revegetation due to the lack of reliable data allowing producing realistic estimates of the activities covered under Article 3.4.[12]

Furthermore, Parties had to elect the accounting frequency for 3.3 and 3.4 activities: annual or at the end of the Commitment Period (for all other sectors the accounting frequency is annually). For the mandatory art. 3.3 and art. 3.4 activities Luxembourg has chosen accounting at the end of the Commitment Period.

1.1.3.2 National registry and Kyoto Protocol Units

Each Party to the Kyoto Protocol has to operate a national registry following the standards as defined in the Data Exchange Standards for Registry Systems under the Kyoto Protocol. The

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11 http://www.ceip.at/ms/ceip_home1/ceip_home/status_reporting

12 Luxembourg's initial report under the Kyoto Protokol for the second commitment period (2013-2020) is available at http://unfccc.int/national_reports/initial_reports_under_the_kyoto_protocol/second_commitment_period_2013-2020/items/9499.php.

registry is an electronic database for the administration of Kyoto units that are used to account for greenhouse gas emissions under the commitments of the Kyoto Protocol. Like banks recording balances and transactions of money in accounts belonging to individuals or other entities, registries record balances of units of greenhouse gas emissions, so called Kyoto units, which are allocated to countries or other entities. The registry ensures the precise tracking of holdings, issuances, transfers, cancellations and retirements of allowances and Kyoto units.

Different types of Kyoto units exist, *e.g.* depending on the source of emissions/removals:

- Assigned Amount Units (AAUs) are the tradable units of the Assigned Amount (AA), which a country with a reduction commitment (Annex B country) gets allocated.
- Removal Units (RMUs) are Kyoto units which Annex B Parties can generate *e.g.* through national afforestation and other sink projects.
- Emissions Reduction Units (ERUs) are generated by Joint Implementation projects.
- Certified Emissions Reductions (CERs) are generated from Clean Development Projects.

Additionally, registries of EC and EEA countries administrate the European Emissions Trading Scheme, the traded units are EU Allowances (EUAs).

For more information on the National Registry and Kyoto Protocol Units, please refer to chapters 12 and 14.

1.2 A Description of the national inventory arrangements

1.2.1 Institutional, legal and procedural arrangements

1.2.1.1 Overview of Luxembourg's obligations

Some obligations are directly linked with GHG emission reporting:

- Annual obligations under Regulation 525/2013/EC of the European Parliament and of the Council of 21 May 2013 on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change (known as Monitoring Mechanism Regulation, MMR) and repealing Decision 280/2004/EC of the European Parliament and of the Council of 11 February 2004 concerning a mechanism for monitoring Community GHG emissions and for implementing the Kyoto Protocol and Commission Decision 2005/166/EC of 10 February 2005 laying down rules implementing Decision 280/2004/EC;
- Obligations under the UNFCCC. Relevant COP Decisions and Guidelines are:

o Decision 3/CP.5 – Guidelines for the preparation of National Communications by Parties included in Annex I to the Convention, Part I: UNFCCC Reporting

Guidelines on Annual Inventories (referring to Document FCCC/CP/1999/7) revised with Decision 18/CP.8 (referring to Document FCCC/CP/2002/8);

- o Decision 4/CP.5 – Guidelines for the preparation of National Communications by Parties included in Annex I to the Convention, Part II: UNFCCC Reporting Guidelines on National Communications (referring to Document FCCC/CP/1999/7) revised with Decision 19/CP.8 (referring to Document FCCC/CP/2002/8);
- o Document FCCC/CP/1999/7 – Review of the Implementation of Commitments and of other Provisions of the Convention – UNFCCC Guidelines on Reporting and Review revised with Document FCCC/CP/2002/8;
- o Decision 11/CP.4 – National communications from Parties included in Annex I to the Convention;
- o Document FCCC/CP/2001/13/Add.3 – Report of the Conference of the Parties on its seventh session, held at Marrakech from 29 October to 10 November 2001, Addendum, Part two: Action taken by the Conference of the Parties, Volume III (Decision 20/CP.7: Guidelines for national systems under Article 5, paragraph 1, of the Kyoto Protocol; Decision 21/CP.7: Good practice guidance and adjustments under Article 5, paragraph 2, of the Kyoto Protocol; Decision 22/C.7: Guidance for the preparation of the information required under Article 7 of the Kyoto Protocol; Decision 23/CP.7: Guidelines for review under Article 8 of the Kyoto Protocol).
- o Decision 24/CP.19 - Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention – introducing the 2006 IPCC Guidelines.

Some provide, indirectly, information that can be used to produce GHG inventories:

- Annual obligations under the UNECE Convention on Long-Range Transboundary Air Pollution (*CLRTAP*) and its Protocols comprising the annual reporting of national emission data on SO_2, NOx, NMVOCs, NH_3, CO, TSP, PM_{10}, and $PM_{2.5}$ as well as on the heavy metals Pb, Cd and Hg and persistent organic hydrocarbons (*PAHs*), dioxins and furans and hexachlorobenzene (*HCB*);
- Annual obligations under Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain atmospheric pollutants, (known as the "NEC Directive") comprising the annual reporting of national emission data on SO_2, NOx, NMVOCs and NH_3;
- Obligations under the European Pollutant Emission Register (EPER), which was the first Europe-wide register for emissions from industrial facilities both into air and water. The legal basis of EPER is Article 15 of the IPPC Directive (EPER Decision 2000/479/EU), which stipulates that information on environmental pollution has to be provided to the public. The reporting years under EPER were 2001 or 2002 and 2004. EPER was replaced by the European Pollutant Release and Transfer Register (E-PRTR) in 2007, which was established by the E-PRTR Regulation No 166/2006.
- Obligations under the framework of the European Union Emission Trading Scheme (EU-ETS) established by Directive 2003/87/EC of the European Parliament. It includes heavy energy-consuming installations in power generation and manufacturing. The activities covered are energy activities, the production and processing of ferrous metals, the mineral industry and some other production activities. From 2012 onwards, CO_2 emissions from aviation have also been

included. For the trading period 2013–2020 the scope of the EU ETS has been further extended to include additional installations from the metal and chemical industry and compressor stations.

1.2.1.2 Luxembourg's National Inventory System

A Grand-Ducal Regulation[13] designates a Single National Entity, the National Inventory Compiler and the National GHG Inventory Focal Point. It also defines and allocates specific responsibilities for the realization of the GHG Inventories both within the Single National Entity and within the other administrations and/or services that are involved in the inventory preparation in the future.

1.2.1.2.1 Single National Entity and other cross-cutting roles

The previously cited regulation designates the Environment Agency (*Administration de l'environnement, AEV*)[14] as the "Single National Entity with overall responsibility for the GHG Inventory". Overall management of the Single National Entity is assigned to one staff member of the Environment Agency that is nominated GHG Inventory Focal Point. The Agency also acts as "National Inventory Compiler" compiling and checking the information and GHG emission estimates coming from sector experts working in other administrations or services.

The Environment Agency has therefore the "technical" knowledge and responsibility for the GHG Inventories, but the "political" responsibility is staying with the Department of the Environment of the Ministry of Sustainable Development and Infrastructures – hereafter designated as MDDI-DEV – acting as UNFCCC National Focal Point. Thus, it is the Ministry that officially submits the inventories and their related reports to the UNFCCC Secretariat and the European Commission (see Article 8 of the Regulation).

Figure 1-1 summarizes the organization of the GHG reporting in Luxembourg in accordance with the national Regulation for the setting-up of a National Inventory System (NIS).

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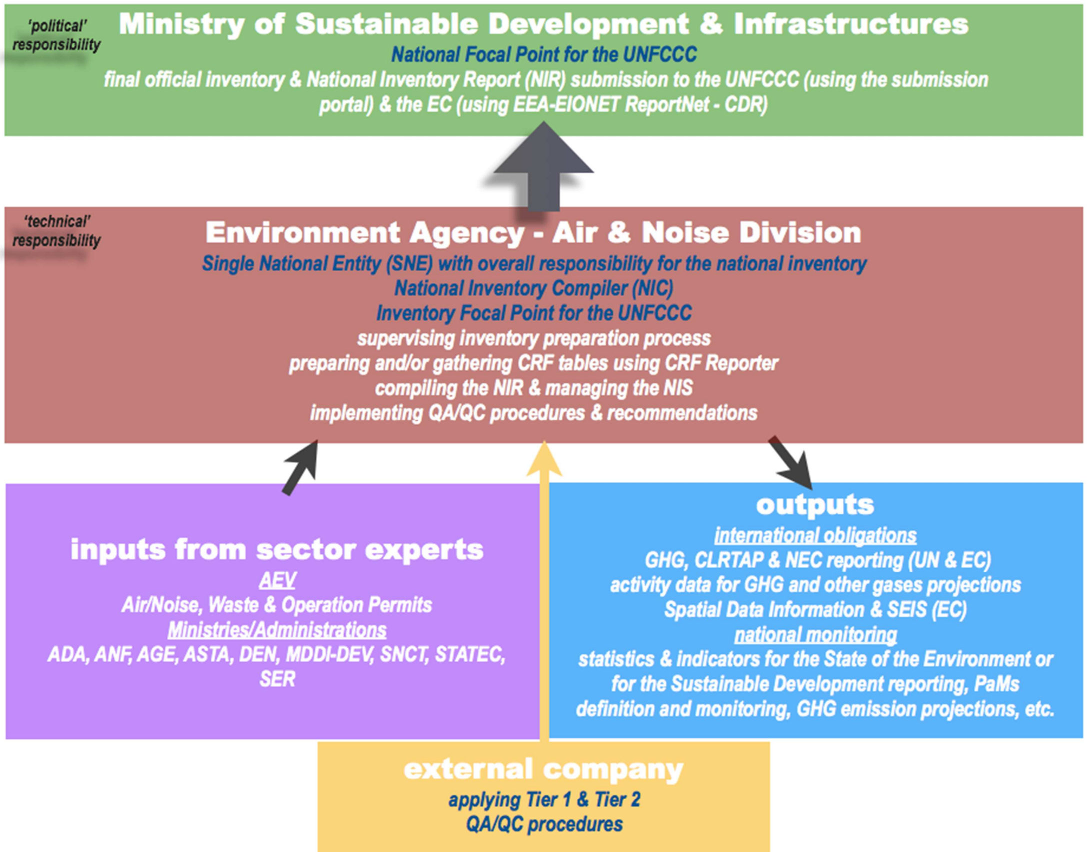
13 Règlement grand-ducal du 1er août 2007 relatif à la mise en place d'un Système d'Inventaire National des émissions de gaz à effet de serre dans le cadre de la Convention-cadre des Nations Unies sur le Changement Climatique, Mémorial A-N° 130 du 7 août 2007, pp. 2318-2320 : see http://www.legilux.public.lu/leg/a/archives/2007/1300708/1300708.pdf.

14 The Environment Agency is directly linked to the Ministry of Sustainable Development and Infrastructures and works under its supervision: see http://www.environnement.public.lu/functions/apropos_du_site/mev/attributions_MEV/index.html and the assignments of the Environment Agency: http://www.environnement.public.lu/functions/apropos_du_site/aev/Missions_aev.html (in French).

Figure 1-1 – Luxembourg's NIS according to the Regulation of 1st August 2007



It is worth noting that the *Unité surveillance et évaluation de l'environnement* of this Agency is not only dealing with GHG reporting but also with reporting under the UNECE LRTAP Convention and under the "NEC Directive".

Luxembourg has, thus, adopted an "integrated approach" to avoid redundant and overlapping activities in different administrative services. This concentration of air emissions reporting in one department also allows an improved consistency between different reporting schemes. As an example, indirect GHG and SO_2 emissions that are to be recorded in the GHG inventory – and that, as indicated previously, need to be re-evaluated in the light of the revision of the inventories Luxembourg is compiling for the UNECE CLRTAP and under the "NEC Directive" – are extracted and adapted from the CLRTAP/NEC reporting schemes.

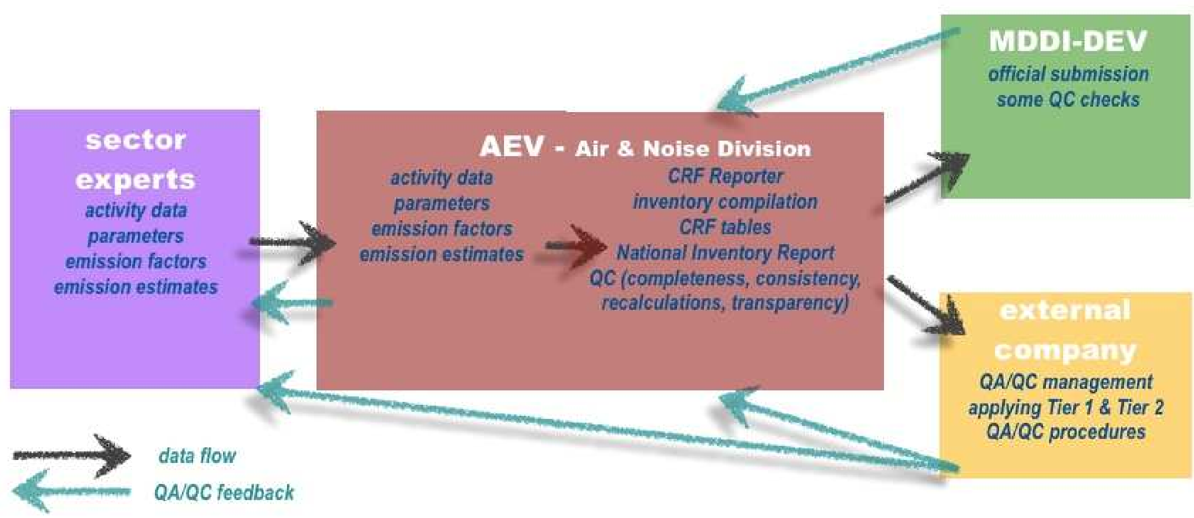
With regard to inputs for the monitoring of GHG emissions, having E-PRTR and EU-ETS managed by the Environment Agency ensures easy access to facilities' reported fuel and/or emissions that are subsequently integrated in GHG emissions calculations. The Environment Agency also gathers information from establishments and installations subordinated to a operational permits to carry out certain activities, the so-called "*établissements classés*". There, too, valuable information for the inventories is found. More details on these AD and, sometimes, EF sources are presented in Section 1.4.

With regards to outputs from the *Unité surveillance et évaluation de l'environnement*, not only are they used for the various inventory reporting obligations (GHG, CLRTAP, NEC), but also for other reporting activities, such as those linked to Spatial Data Information (such as the EC INSPIRE Directive[15]) and under the Shared Environmental Information System.[16] Of course, these are also used for various national publications, as well as, for defining policies and measures (*PaMs*).

Finally, although the national regulation, setting up the NIS, only indicates that an agent, belonging to the Environment Agency, should develop, implement and maintain a QA/QC plan, it has been decided that QA/QC activities should be performed by an external company so to guarantee an independent review process (see Section 0).

Figure 1-2 goes over the data flow process that is implied by the setting-up of the NIS. The *Unité surveillance et évaluation de l'environnement* of the Environment Agency not only collects and validates AD, EF, parameters and emission estimates from sector experts and compiles the inventories, but also produces emission estimates. This flexibility is introduced in Luxembourg's system to ensure a better quality for the reporting of GHG emissions.

Figure 1-2 – Theoretical data flow according to Luxembourg's NIS



1.2.1.2.2 Specific responsibilities for the GHG Inventory compilation and development process

Article 3 of the Regulation presents the tasks of the Single National Entity. In a few words, the Single National Entity – *i.e.* the Environment Agency – provides sector experts for all the IPCC

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15 See http://inspire.jrc.it/

16 See http://ec.europa.eu/environment/seis/index.htm

Sectors except Agriculture, LULUCF and Wastewater Handling (see Table 1-1). It is also the Agency that:

- manages the NIS and coordinates the work on GHG Inventories by informing the experts of any changes and evolutions in the Guidelines;
- as National Inventory Compiler (NIC), compiles the GHG emissions estimates produced by sector experts;
- prepares the NIR (notably on the basis of chapters received from the sector experts), including the Key Category Analysis (*KCA*) and the calculation of the uncertainties;
- prepares and defines work plans to secure timely data supply;
- assists sector experts in their assignments and their training;
- defines and approves, together with sector experts, activity/background data (*AD*), emission factors (*EF*), methods to estimate GHG emissions;
- archives the relevant information on the inventories and the NIS;
- implements recommendations from the quality assurance/quality control (*QA/QC*) annual exercise (see Section 1.6).

Article 4 describes the tasks that fall to sector experts:

- choice of the best methods to evaluate GHG emissions, using IPCC Guidelines (these methods have to be approved by the Single National Entity as indicated above);
- collection of the necessary AD and EFs;
- calculation of emission estimates;
- recalculation of emission estimates when possible and desirable: new AD sources, new parameters, new methods, *etc.*;
- proceeding with first quality checks (using, inter alia, tools embedded in CRF Reporter that allow to verify completeness and consistency);
- preparation of the NIR relevant chapters.

Finally, Article 5 indicates that activity/background data providers have to transmit quality AD using formats, and respecting the deadlines, defined by the Single National Entity.

Table 1-1 – CRF Sector responsibilities within the NIS

CRF Sector	AD	Choice of EFs	Emissions estimation methods
Energy, excl. road transportation – CRF 1 except 1A3b	AEV – STATEC	AEV	AEV
Road transportation – CRF 1A3b	AEV – STATEC – SNCT	AEV	AEV
Industrial Processes – CRF 2	AEV	AEV	AEV
Agriculture – CRF 3	ASTA – SER	ASTA – SER	ASTA – SER
LULUCF – CRF 4	ANF – SER – ASTA - AEV	ANF – SER – ASTA - AEV	ANF – SER – ASTA – AEV
Waste – CRF 5A, 5B & 5D	AEV	AEV	AEV
Wastewater Handling – CRF 5B	AGE	AGE	AGE

Abbreviations used in Table 1-1:

Ministry of Agriculture:

ASTA = Agriculture Technical Services Administration (*Administration des Services Techniques de l'Agriculture*): http://www.asta.etat.lu/

SER = Agriculture Economic Service (*Service d'Economie Rurale*): http://www.ser.public.lu/

Ministry of Economic Affairs & External Trade:

STATEC = National Statistical Institute: http://www.statec.public.lu/fr/index.html

Ministry of Sustainable Development and Infrastructures (MDDI): http://www.emwelt.lu/:

ANF = Nature & Forestry Administration (*Administration de la Nature et des Forêts*)

AEV = Environment Agency (*Administration de l'Environnement*)

AGE = Water Management Administration (*Administration de la Gestion de l'Eau*): http://www.eau.public.lu/

Ministry of Transport:

SNCT = Technical Vehicle Inspection Administration (*Société Nationale de Contrôle Technique*): http://www.snct.lu/snct/home.nsf

1.2.1.2.3 Luxembourg's emissions trading registry

Luxembourg's emissions trading registry has been operational since 2005 and serves both as registry for the EU Emissions Trading Scheme, and as the national registry for Luxembourg as a Party of the Kyoto Protocol.

Since July 2013, Luxembourg's national registry was migrated to a European based consolidated system operated by the European Commission. Please refer to Chapter 14 for more information on the consolidated system.

1.2.2 Overview of inventory planning, preparation and management

The main planning of Luxembourg's GHG inventory is performed once a year during summer at the so called Decision Making Body meeting: a meeting between the Director of the Environment Agency, the head of the *Unité surveillance et évaluation de l'environnement*, the quality manager, and the national inventory compiler.

During the meeting, the quality manger and the national inventory compiler present an overview of the activities, during the previous reporting year, including information on audits and fulfilments of last year's improvement plan. On the basis of this report, the quality management system (QMS) is judged by the director and the head of the *Unité surveillance et évaluation de* *l'environnement*, in collaboration with the quality manager and the national inventory compiler. If required, measures to optimize the QMS are defined. Finally, the improvement plan is elaborated on the basis of the previously conducted discussions. It consists of two parts:

- Quality management improvement plan: bases on findings of internal and external audits; it also includes a training plan for sector experts.
- Inventory improvement plan: bases on particular findings of reviews of the GHG inventory.

The decision making body prioritises the recommended improvements (including a timeline and responsibilities) and cares for associated resources.

Table 1-2 gives an overview on the tasks of inventory preparation together with a typical timeline.

Table 1-2– Inventory preparation timeline

Task	Description	Deadline
Decision making body meeting	Evaluation of the fulfilment of the previous improvement plan Preparation of a plan for QMS and inventory improvement, i.a. based on audit and review findings.	Summer
Kick-Off	Meeting of sector experts, quality manager and national inventory comiler; definition of a work plan	Summer
Activity data collection	Collection of activity data, including contracting out studies.	November 1st
Inventory preparation	Estimation of emissions for all sources, including collection of background data.	December 1st
Compilation of national inventory	Stocking the database and transfer to CRF reporter ; key category analysis and uncertainty assessment	December 31
Quality checks	Tier 1 and Tier 2 QA/QC activities	December
Compilation of report (Short-NIR)	Compilation of an inventory report “Short NIR” and submission to the European Commission (Decision 280/2004/EC)	January 15
Preparation of NIR	Compilation of the National Inventory Report	January - March
EU Submission NIR	Submission of the National Inventory Report to the EC	March 15
UNFCCC Submission NIR	Submission of the National Inventory Report to the UNFCCC	April 15
Archive submission	All relevant calculation and documentation files as well as the NIR are archived on CIRCALUX	May

Table 1-3 gives an overview on the registry related tasks for providing the supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol including a timeline.

Table 1-3– Timeline for registry related tasks

Task	Description	Deadline
Standard Electronic Format (SEF)	Compilation of the SEF for the previous year	January 15
Information on changes in the national registry	Preparation of the chapter on the changes in the national registry, which is part of the NIR	March 15
Information on accounting of Kyoto Protocol units	Preparation of the chapter on information on the accounting of Kyoto Protocol units, which is part of the NIR. Compilation of the files for the Standard Independent Assessment Report (SIAR), which are submitted together with the NIR.	March 15

Finally, an official approval process has been established between the Single National Entity (SNE, Environment Agency) and the UNFCCC National Focal Point (NFP, MDDI). Thus, the SNE notifies the NFP, in writing, that the inventory has been compiled according to the rules established by the UNFCCC and uploads the submission onto the CIRCALUX data archive (see Section 1.3). The NFP informs the Minister in charge of environmental affairs accordingly. Upon acceptance, the NFP uploads the submission from the CIRCALUX archive onto the UNFCCC submission portal and onto the European central data repository hosted by the EEA.[17]

1.3 Inventory preparation, and data collection, processing and storage

1.3.1 GHG Inventory and KP-LULUCF inventory

Luxembourg's greenhouse gas inventory for the period 1990 to 2015 was compiled according to the recommendations for inventories set out in the revised UNFCCC reporting guidelines according to Decision 24/CP.19. IPCC Guidelines have been applied as much as possible. These Guidelines are:

- the 2006 IPCC Guidelines for National Greenhouse Gas Inventories[18];
- the 2013 Revised Supplementary Methods and Good Practice Gudance arising from the Kyoto Protocol.

During the inventory preparation process, sector experts collect activity data, emission factors and all relevant information needed for estimating the emissions. The sector experts also have specific responsibilities regarding the choice of methods, data processing and archiving and for contracting studies, if needed. As part of the quality management system, the national inventory compiler approves the methodological choices. Sector experts are also responsible for performing Quality Control (QC) activities that are incorporated in the Quality Management System (QMS). All data collected together with emission estimates are archived on a central archiving system (see below), together with the well documented data sources in order to be able to perform future reconstructions of the inventory.

Supplementary information required under Article 7 of the Kyoto Protocol regarding KP-LULUCF is prepared by the same sector experts as for UNFCCC-LULUCF. Other Article 7 supplementary information is requested from Luxembourg's Emission Trading Registry, which is also located at the Environment Agency.

17 See also article 8 of the Grand-Ducal Regulation of August 1st, 2007 relative to the implementation of the NIS.

18 http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm

1.3.2 Data collection, processing and storage, including for KP-LULUCF inventory

For estimating GHG emissions, Luxembourg mostly used Microsoft Excel™ spreadsheets (Table 1-4).

Table 1-4 – Programs and software used for generating emission estimates

CRF Sector	Emissions calculated using …
Energy, excl. road transportation – CRF 1 except 1A3b	MS Excel 2010
Road transportation – CRF 1A3b	NEMO IV and MS Excel 2010
Industrial Processes – CRF 2	MS Excel 2010
Agriculture – CRF 3	MS Excel 2010
LULUCF – CRF 4	MS Excel 2010
Waste – CRF 5	MS Excel 2010

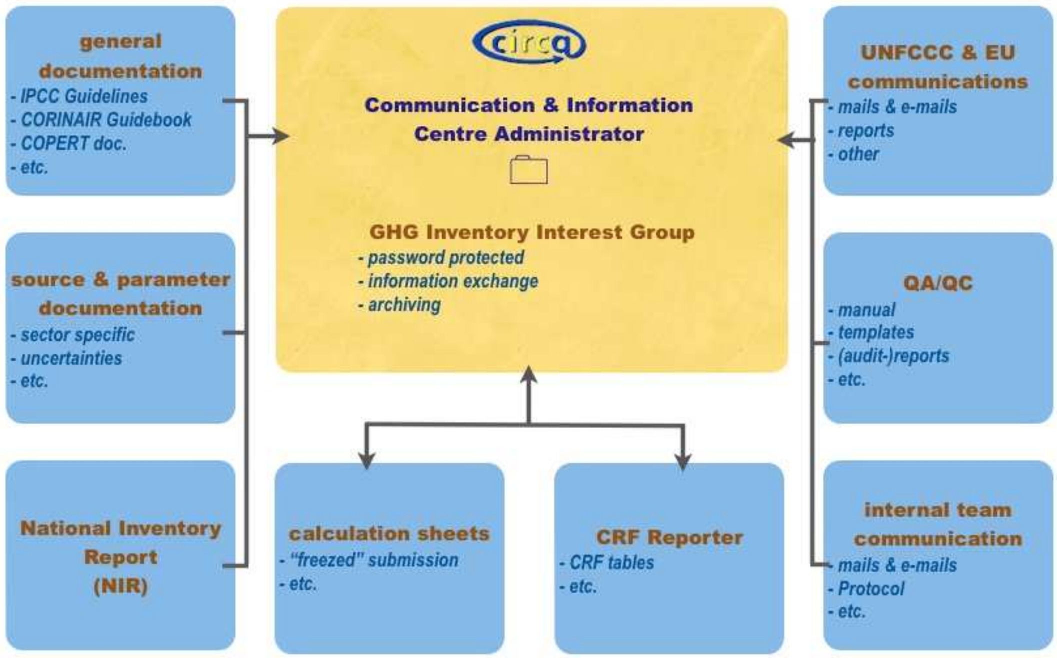
This way of proceeding offers a very flexible system that can be easily adjusted to new requirements. It is only for the estimation of road transportation emissions, where a dedicated model is used:

NEMO IV v10.0 *is a Microsoft Windows™ software tool for the calculation of emissions from road transport. The emissions calculated include all major pollutants (CO_2, CO, CH_4, NO_x, VOC, and PM) and several more (N_2O, NH_3, SO_2...). Data produced is then transformed using MS Excel spreadsheets into the UNFCCC common reporting format, according to the IPCC Guidelines, to comply with the reporting obligations under the UNFCCC.*

GHG emission estimates produced by the sector experts are then being centralized and verified by the Single National Entity (*i.e.* the National Inventory Compiler (Environment Agency)).

A centralised data management and archiving system (based on the European Data Exchange and Storage System CIRCA) has been implemented (Figure 1-3). This system is hosted by the National IT Administration, and access is password protected. This system enables sector experts to quickly and easily exchange and store data between administrations, which are not connected through a single network. The data stored on this system are backed up daily for the needs of data security. Furthermore, as part of the QMS, backups of the entire inventory information are made regularly on write-protected DVDs. This ensures the necessary documentation and archiving for future reconstruction of the inventory and for the timely response to requests during the review process.

Figure 1-3 – Data management and archiving system (CIRCALUX)



For the generation of the CRF tables and the XML submission file, Luxembourg used the latest version of the UNFCCC's CRF-Reporter, *i.e.* version 3.6.2. As a large number of GHG source categories are not occurring in Luxembourg, only around a hundred values per inventory year – other than notation keys – need to be transferred to the CRF-Reporter. This is why, so far, CRF Reporter has been "manually" populated by having recourse to "copy-paste" from Microsoft Excel™ inventory work files.

However, with the increasing number of LULUCF data, which needs to be transferred to the CRF-Reporter, this manual data transfer becomes prone to errors. Therefore, it is foreseen to centralise the emission estimates (and all the associated data such as EFs, AD, Documentation, etc) in a centralised database. Specific software tools embedded in this database would then allow the automatic data transfer into the CRF-reporter software, without the need of the "copy-paste" procedure. Currently, Luxembourg is in the process of switching to the centralised database, and it is expected that the automatic transfer will be used for the next submission. Nevertheless, this is not an absolute "must do" for Luxembourg since, as underlined above, yearly data to be included in CRF Reporter are not numerous. Furthermore, "manually" populating CRF Reporter offers concrete advantages compared to automated operations: mistakes and missing values can be directly identified, recalculations cross-checked, explanations for notation keys or recalculations not forgotten and documentation boxes filled accordingly when needed.

1.3.3 Quality assurance/quality control (QA/QC) procedures and extensive review of GHG inventory and KP-LULUCF inventory

QA/QC procedures are performed as defined in the QMS plan (see Chapter 0).

Quality assurance, control and plausibility assessments of the estimates are being performed through internal audits covering all sectors, by the SNE in collaboration with the QA/QC manager[19]. In addition, various checking procedures, included in the CRF-Reporter software are undertaken.

The NIR is circulated after publication to experts that are involved in the estimation on greenhouse gas emissions in Luxembourg as identified by the National Inventory Compiler and the QA/QC manager.

Comments received from experts are considered for the inventory improvement plan.

1.4 Methodologies and Data Sources Used

1.4.1 GHG inventory

The following table briefly presents the activity data (AD) sources, the types of emission factors (EF) used, as well as the methods applied for estimating GHG emissions reported in this submission. A more detailed listing can be found in CRF table Summary 3.

Table 1-5 – Methodologies, data sources and EFs used by Luxembourg – main CRF Sectors

CRF Sector	CO_2			CH_4			N_2O		
	Method applied	*AD*	*EF*	*Method applied*	*AD*	*EF*	*Method applied*	*AD*	*EF*
Energy, excl. road transportation – CRF 1 except 1A3b	Tier 1 Tier 2	NS PS Q TÜV	D CS PS	Tier 1	NS PS Q TÜV	D	Tier 1	NS PS Q TÜV	D
Road transportation – CRF 1A3b	CIV CS	NS SNCT	CS	CIV	NS SNCT	OTH	CIV	NS SNCT	OTH
Industrial Processes – CRF 2	Tier 2 CS	NS PS	CS PS	NA	NO	NA	NA	NO	NA
Agriculture – CRF 3	NA	NA	NA	Tier 1 Tier 2	EJ NS	CS D OTH	Tier 1	EJ NS	D
LULUCF – CRF 4	Tier 1 Tier 2	NS EJ	CS D	NA	NA	NA	Tier 1	NS EJ	D
Waste – CRF 5	NA	NA	NA	Tier 1 Tier 2	NS Q PS	CS D	Tier 1	NS Q PS	PS D

19 Currently contracted from SEG-Umwelt Service GmbH (Mettlach, Germany).

Note: for F-gases (IPCC Category 2F) methods applied = CS; AD = NS & Q; EF = CS.
Abbreviations:

C = CORINAIR	CS = Country Specific	CIV = NEMO	D = IPCC Default
EJ = Expert Judgement	NS = National Statistics	OTH = Other	PS = Plant Specific Data

Q = Specific Questionnaire/Survey/Annual Reports TÜV = TÜV Rheinland, *Emissionskataster für das Großherzogtum Luxemburg*, Köln, 1990

Detailed information on data sources for activity and emission data, as well as for EFs used by sector, can be found in the methodological chapters of this report (chapter 3 to 7). A few general comments are, however, presented in the next sub-sections.

1.4.1.1 Activity and background data

Data used to produce the annual air emission (including GHG) inventories are mainly:

- taken from official statistics published by the National Statistical Institute (STATEC). Concerning energy data (energy balance), STATEC has recently developped a new system for data collection, treatment, checking and compilation. This new system was implemented in such a way to ensure that both the needs of public administrations dealing with energy questions and the reporting obligations to the European regulation 1099/2008/EC on energy statistics and to the IEA (IEA Joint Questionnaires[20]), are fulfilled. The data sources and methodologies for preparing Luxembourg's energy balance as well as the new compilation system are described in STATEC 08_2010[21];
- extracted from statistical information received by other ministries and public administrations;
- coming from information supplied directly by facilities (annual reports, emission measurement reports);
- on occasion, from specific surveys or questionnaires and from expert judgements.

For large point sources – and after careful assessment of data plausibility – activity data that are reported by facilities are preferably used. Indeed, these data usually reflect the actual consumptions better than aggregated national statistics data, because the facility is supposed

[20] The energy balance is based on several databases mainly prepared by:
- Ministère de l'Economie et du Commerce Extérieur
- Ministère du développement durable et des infrastructures (département de l'environnement, département du transport
- Administration de l'environnement: *Unité surveillance et évaluation de l'environnement*, *Unité permis et subsides*, *Registre des quotas d'émissions à effet de gaz de serre (ETS)*;
- Administration des Douanes et Accises (Ministère des Finances);
- Service Central de la Statistique et des Etudes Economiques (STATEC);
- Société Nationale des Chemins de fer Luxembourgeois (CFL)
- all relevant fuel importers and distributors;
- plant operators;

The methodology used to compile the enrgey balance follows the International Energy Agency (IEA) and Eurostat conventions. The aggregated balances are harmonised with the IEA tables.

[21] http://www.statistiques.public.lu/catalogue-publications/bulletin-Statec/2010/PDF-Bulletin-8-2010.pdf

having the best information about its own emissions. Such plant specific data have been used for CRF sectors 1 and 2.

Besides plant specific data collected under EU legal requirements, national obligations are also a source of activity and emission data for single facilities. This is the case under the law for "*établissements classés*"[22] that imposes regular reporting obligations to those units – the "*établissements classés*" – which, by their activities, could represent a risk with regards to security, public health and convenience for both the citizens and the workers occupied in these units, as well as regards the environment.[23] These "*établissements classés*" could be public or private industrial or commercial establishments and craft industries, as well as single specific equipments or processes within an installation.

Most of the plant specific data, whether they are collected for european or national obligations, are actually transmitted and managed by the Environment Agency which eases a more systematic use of data provided directly by facilities. In particular, it is investigated whether it will be feasible, both technically and legally, that facilities would report only once for various purposes – such as EU-ETS, E-PRTR, permitting activities, *etc.* – in order to avoid extra and unnecessary burden for them.

1.4.1.2 Emission factors

For EFs, besides country-specific and plant specific factors derived from emission data transmitted by facilities (see above), it is also made use of default IPCC values published in the 2006 IPCC Guidelines, as well as in the 2013 KP Supplement for LULUCF. Other sources for EFs are the EMEP/EEA air pollutant emission inventory guidebook — 2013[24] and national / international studies or calculations leading to country-specific EFs.

1.4.2 KP-LULUCF inventory

Land use and land use change data are based on commercial satellite imagery, land cover maps held by the Nature and Forestry Aadministration and on information on agricultural practices from the Service of Rural Economics. These two institutions are the main data providers for the greenhouse gas reporting in the frame of the KP-LULUCF inventory.

Accordingly, the area of forest land reported for Afforestation/Reforestation and Deforestation (ARD) under the Kyoto Protocol has the same basis as the area reported for Land use changes from

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22 See http://www.environnement.public.lu/etablissements_classes/index.html (in French).

23 "Permitting activities", *i.e.* activities subordinated to a permit.

24 http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2013

and to forests in the UNFCCC greenhouse gas inventory taking the different time frame (ARD areas starting with 1990) as well as the permanence of ARD areas into account.

Furthermore the methods used to estimate emissions/removals from ARD activities are of the same Tier method as those used for the UNFCCC reporting. These are described in detail in Chapter 11.

1.5 Brief description of key categories

The identification of key categories is described in Chapter 4 of the 2006 IPCC Guidelines. It stipulates that a key category is one that is prioritised within the National System because its estimate has a considerable influence on a country's total inventory of GHG in terms of the absolute level of emissions or removals, the trend in emissions or removals, or both. Any category meeting the 95% threshold in any year of the Level Assessment (*LA*) or in the Trend Assessment (*TA*) is considered a key category. Then, whenever a method used for the estimation of emissions/removals of a key category is not consistent with the requirements of the 2006 IPCC Guidelines, the method will have to be improved to reduce uncertainty, which is considered in the emission inventory improvement programme (see Chapter 9).

All notations, descriptions of identification and results for key categories included in this section are based on the 2006 IPCC Guidelines. The identification includes all reported GHG CO_2, CH_4, N_2O, HFC, PFC and SF_6, and all IPCC categories.

The key category analysis was performed using the Tier 1 approach based on submission 2017v1.2. It comprises a level assessment for all years between 1990 and 2015, as well as a trend assessment for the trend of the year 2015 with respect to base year emissions, *i.e.* 1990 (1995 for F-gases). Key categories have been identified excluding LULUCF categories and for the full inventory including LULUCF categories.

1.5.1 GHG inventory (including and excluding LULUCF)

1.5.1.1 Level Assessment (Tier 1)

The identified key categories (LA) are listed in Table 1-6 (excl. LULUCF) and Table 1-8 (incl. LULUCF). The key categories without LULUCF comprise 9810.37 Gg CO_2e in the year 2015, which is a share of 95.52% of Luxembourg's total GHG emissions, excluding LULUCF.

Table 1-6 – Key categories (Tier 1, LA) excluding LULUCF based on emission data reported in submission 2017v1.2

IPCC category	Category name	Fuel	Gas	2015 emissions in Gg CO2e	Share in 2015 national total GHG emissions (excl. LULUCF)
1A1	Fuel combustion - Energy industries	gaseous	CO_2	368,54	3,59%

1A1	Fuel combustion - Energy industries	other	CO_2	82,88	0,81%
1A2	Fuel combustion - Manufacturing Industries and Construction	liquid	CO_2	198,49	1,93%
1A2	Fuel combustion - Manufacturing Industries and Construction	solid	CO_2	162,90	1,59%
1A2	Fuel combustion - Manufacturing Industries and Construction	gaseous	CO_2	697,52	6,79%
1A3b	Road Transportation	gasoline	CO_2	883,90	8,61%
1A3b	Road Transportation	Diesel oil	CO_2	4748,46	46,23%
1A4	Fuel combustion – Other sectors	Liquid	CO_2	787,76	7,67%
1A4	Fuel combustion – Other sectors	gaseous	CO_2	762,04	7,42%
1A5	Fuel combustion – Other	liquid	CO_2	0,12	0,00%
2A1	Cement production		CO_2	329,47	3,21%
2A3	Glass production		CO_2	65,06	0,63%
2C1	Iron & steel production		CO_2	122,80	1,20%
2F1	Refrigeration and air conditioning		F-gases	63,27	0,62%
3A	Enteric fermentation		CH_4	429,60	4,18%
3B	Manure management		CH_4	64,19	0,63%
3D1	Direct N_2O emissions from managed soils		N_2O	106,75	1,04%
5A	Solid waste disposal		CH_4	53,17	0,52%
All	**Sum of all key categories**	**all**	**all**	**9810.37**	**95.52%**

Table 1-7 specifies for which years any source category has been identified as key category (LA) for from 1990 to 2015 (excl. LULUCF).

Table 1-7 – Key categories (Tier 1, LA) excluding LULUCF of submission 2017v1.2: 1990-2015

IPCC source category	gas	fuel	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1A1 - Energy Industries	CO2	gaseous									X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1A1 - Energy Industries	CO2	other									X													X	X	X	X	X
1A2 - Manuf. Ind. And Constr.	CO2	liquid	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1A2 - Manuf. Ind. And Constr.	CO2	solid	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1A2 - Manuf. Ind. And Constr.	CO2	gaseous	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1A3b - Road transportation	CO2	gasoline	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1A3b - Road transportation	CO2	diesel oil	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1A4 - Other sectors	CO2	liquid	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1A4 - Other sectors	CO2	gaseous	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1A5 - Other	CO2	liquid										X																
2A1 - Cement production	CO2		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2A3 - Glass production	CO2												X										X				X	X
2C1 - Iron & steel production	CO2		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2F1 - Refrig. And air cond.	F-gases																										X	
3A - Enteric ferm.	CH4		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3B - Manure man.	CH4							X	X	X	X	X	X	X	X										X	X		X
3D1 - Direct emissions from man. Soils	N2O		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
5A - solid waste disp.	CH4							X	X	X	X	X	X	X	X	X	X			X	X	X						

Table 1-8 indicates which source categories – including LULUCF - have been identified as key categories (LA) for at least one reported year from 1990 to 2015. The key categories comprise 9385.48 Gg CO_2e in the year 2015, which is a share of 95.15% of Luxembourg's 2015 total GHG emissions, including LULUCF.

Table 1-8 – Key categories (Tier 1, LA) including LULUCF based on emission data recorded in submission 2017v1.2

IPCC	IPCC source category	Fuel	Gas	2015 emissions in Gg CO_2e	Share in 2015 national total GHG emissions (incl. LULUCF)
1A1	Fuel combustion - Energy industries	gaseous	CO_2	368,54	3,74%
1A2	Fuel combustion – Manufacturing industries and construction	gaseous	CO_2	697,52	7,07%
1A2	Fuel combustion – Manufacturing industries and construction	liquid	CO_2	198,49	2,01%
1A2	Fuel combustion – Manufacturing industries and construction	solid	CO_2	162,90	1,65%
1A3b	Fuel combustion – Transport - Road transportation	diesel oil	CO_2	4748,46	48,14%
1A3b	Fuel combustion – Transport - Road transportation	gasoline	CO_2	883,90	8,96%
1A4	Fuel combustion – Other sectors	gaseous	CO_2	762,04	7,73%
1A4	Fuel combustion – Other sectors	liquid	CO_2	787,76	7,99%
2A1	Cement production		CO_2	329,47	3,34%
2C1	Iron and steel production		CO_2	122,80	1,24%
3A	Enteric fermentation		CH_4	429,60	4,36%
4A1	Forest Land remaining Forest Land		CO_2	378,19	3,83%
4A2	Land converted to Forest Land		CO_2	101,48	1,03%
all	**Sum of all key categories**	**all**	**all**	**9385,48**	**95,15%**

Table 1-9 specifies for which years any source category has been identified as key category (LA) for from 1990 to 2015 (incl. LULUCF).

Table 1-9 – Key categories (Tier 1, LA) including LULUCF based on emission data recorded in submission 2017v1.2: 1990-2015

IPCC source category	gas	fuel	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1A1 - Energy Industries	CO2	gaseous													X	X	X	X	X	X	X	X	X	X	X	X	X	X
1A2 - Manuf. Ind. And Constr.	CO2	liquid	X	X																			X	X				
1A2 - Manuf. Ind. And Constr.	CO2	solid	X	X	X	X	X	X	X	X													X	X				
1A2 - Manuf. Ind. And Constr.	CO2	gaseous	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1A3b - Road transportation	CO2	gasoline	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1A3b - Road transportation	CO2	diesel oil	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1A4 - Other sectors	CO2	liquid	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1A4 - Other sectors	CO2	gaseous	X	X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2A1 - Cement production	CO2		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2C1 - Iron & steel production	CO2		X	X	X	X	X	X																				
3A - Enteric ferm.	CH4		X	X	X		X		X		X	X	X	X					X	X	X	X	X	X	X	X	X	X
4A1 - FL remaining FL	CO2				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X
4A2 - Land converted to FL	CO2		X																				X					

The key category with the highest contribution to the national total emissions in 2015 is *1A3b Road Transportation – diesel oil (CO_2)*. The contribution to the national total emissions in the base year was 9.93%, whereas in 2015 this contribution has increased to 46.23%.[25] This strong increase is due to the general increase of road performance, but also due to a shift from gasoline to diesel driven vehicles. Category *1A3b Road Transportation – diesel oil (CO_2)* is the most important category in terms of emission trends and, since 1990 emissions have increased by 276%.

The second most important source of greenhouse gas emissions in 2015 in Luxembourg is *1A3b Road Transportation – gasoline (CO_2)*. Its contribution to national total emissions is 8.61% for 2015 compared to 9.85% in the base year, followed by *1A4 – Other sectors – liquid fuels (CO_2)* with a contribution of 7.67% in 2015 (7.65% in 1990).

The key category with the highest contribution to national removals is *4.A.1 Forest land remaining forest land (CO_2)*. In the key category analysis including LULUCF it is the seventh largest category in the level assessment (3.83% in 2015) and is also a key category in the trend assessment. Removals from this category increased by 674 % from 1990 to 2015. This sharp increase is mainly due to the fact that in 1990 this category was still a net source (see Section 6.2 for more details).

1.5.1.2 Trend Assessment (Tier 1)

Table 1-10 presents the key categories (excluding and including LULUCF) according to the trend assessment for the year 2015.

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25 The percentages given here are those obtained by the level assessment excluding LULUCF.

Table 1-10 –Key categories (excluding and including LULUCF) according to the trend assessment for 2015.

IPCC Category	Category Name	Fuel	GHG	TA excl. LULUCF	TA incl. LULUCF
1A1	Energy Industries	other	CO_2		X
1A1	Energy Industries	other	CH_4		X
1A1	Energy Industries	other	N_2O		X
1A1	Energy Industries	biomass	CH_4		X
1A1	Energy Industries	biomass	N_2O		X
1A2	Manufacturing Industries and Construction	gaseous	CO_2	X	
1A2	Manufacturing Industries and Construction	liquid	CO_2		
1A2	Manufacturing Industries and Construction	solid	CO_2	X	X
1A2	Manufacturing Industries and Construction	liquid	CH_4		X
1A2	Manufacturing Industries and Construction	solid	CH_4		X
1A3a	Aviation	aviation gasoline	CO_2		X
1A3b	Road Transportation	diesel oil	CO_2	X	
1A3b	Road Transportation	gasoline	CO_2	X	
1A3b	Road Transportation	gasoline	CH_4		X
1A3b	Road Transportation	LPG	CH_4		X
1A3b	Road Transportation	gasoline	N_2O		X
1A3b	Road Transportation	LPG	N_2O		X
1A3c	Navigation	liquid	CH_4		X
1A3c	Navigation	liquid	N_2O		X
1A4	Other Sectors	gaseous	CO_2	X	
1A5	Other	liquid	CO_2		X
2A1	Cement Production		CO_2	X	
2C1	Iron & Steel Production		CO_2	X	
Source: Environment Agency					

1.5.2 KP-LULUCF inventory

According to the IPCC GPG for LULUCF, the key categories for Kyoto Protocol activities can be derived from the identified key categories in the UNFCCC inventory as follows: Whenever a category is identified as key in the UNFCCC inventory, the associated activity under the Kyoto-Protocol can be considered as key in reporting under the Kyoto-Protocol[26].

The key category analysis was performed using the Tier 1 approach on the basis of submission 2017v1.2 to the UNFCCC. It comprises a level assessment for all years between 1990 and 2015, as well as a trend assessment for the trend of the year 2015 with respect to base year emissions, *i.e.* 1990. As stipulated in the IPCC-GPG-LULUCF, key categories have been identified, for the full inventory, including LULUCF categories.

Afforestation and Reforestation, Deforestation, and Forest Management are considered key categories according to a quantitative analysis (please see also section 11.6.1).

1.6 Information on the QA/QC plan including verification and treatment of confidentiality issues where relevant

The overall responsibility for the establishment and existence of a Quality Management System (QMS), in order to prepare the national inventory of greenhouse gases and air pollutants, lies with the Environment Agency (Administration de l'environnement, AEV).

Being designated by a grand-ducal regulation[27] as the single national entity (SNE), the AEV, has the overall technical responsibility for the national GHG Inventory. Political responsibility lies with the Ministry of Sustainable Development and Infrastructure (MDDI). Within the AEV, the *Unité surveillance et évaluation de l'environnement* is responsible for the following tasks:

The National Inventory Compiler (NIC):

- supervises the inventory preparation process for various obligations as outlined below;
- is the national inventory focal point to the Ministry (MDDI).

The national, European and international obligations are:

- UNECE Convention on Long Range Transboundary Air Pollution and its protocols
- UNFCCC & Kyoto Protocol
- European Union:

[26] IPCC Good Practice Guidance for LULUCF, Section 5.4.2. and Table 5.4.1.

[27] Grand-Ducal Regulation (Règlement grand-ducal du 1 août 2007)

- o EU GHG Monitoring Mechanism (525/2013/EC (repealing 280/2004/EC) & 2005/166/EC)
- o NEC Directive (2001/81/EC)
- o Ambient Air Quality Directive (2008/50/EC).

1.6.1 Quality Policy

The quality policy is the central aspect of a Quality Management System. It defines the understanding of quality in relation to all topics of inventory preparation and specifies its basic principles.

The single national entity has:

- to establish and maintain the quality policy and quality objectives regarding GHG Inventories;
- to promote the quality policy and quality objectives regarding GHG Inventories throughout the organisation to increase awareness, motivation and involvement;
- to ensure focus on the fulfilment of the Kyoto Protocol and the requirements of the IPCC GPG Chapter 8 QA/QC;
- to ensure that appropriate processes are implemented to enable requirements of the IPCC GPG Chapter 8 QA/QC (and other interested parties) to be fulfilled and quality objectives to be achieved;
- to ensure that an effective and efficient QMS is established, implemented and maintained in order to achieve these quality objectives;
- to ensure the availability of necessary resources;
- to review the Quality Management System periodically;
- to decide on actions regarding the quality policy and quality objectives regarding GHG Inventories;
- to decide on actions for the improvement of the Quality Management System;
- to decide on actions for the improvement of national GHG inventories.

1.6.2 Quality Management System Build-up

The build-up of the Quality Management System (*QMS*) of the GHG emission reporting is currently outsourced and supervised by SEG Umwelt-Service GmbH[28].

Luxembourg's QMS follows a Plan-Do-Check-Act-Cycle (PDCA-cycle)[29], which is an accepted model for pursuing a continual improvement of performance according to international standards

28 SEG Umwelt-Service GmbH, Auf der Haardt 2, D – 66693 Mettlach, http://www.seg-online.de

29 http://www.asq.org/learn-about-quality/project-planning-tools/overview/pdsa-cycle.html

and is in line with procedures described in decision 19/CMP.1 and in the IPCC Good Practice Guidance.

Due to Luxembourg's clear extent, its QMS deals with a manageable quantity of documents. Following are the specifications of Luxembourg's Quality Management System:

- firm build-up with a quality manual consisting of a chart with all relevant documents, handling instructions and deadlines for check (Figure 1-4);
- good manageability (instead of a complex system);
- usable and effective quality control procedures (user-friendly, clearly arranged).

Since the QMS has been implemented in the year 2008, it has evolved continuously and many improvements have already been realised.

The QMS shall ensure and continuously improve the quality (measured by transparency, accuracy consistency, comparability, completeness (TACCC) and timeliness) of Luxembourg's GHG Inventory in order to fulfil the party's obligations according to articles 3, 5 and 7 of the Kyoto Protocol. The QMS therefore supplies procedures to:

- check integrity, correctness and completeness of data;
- identify errors and omissions;
- reduce uncertainties of emission estimates;
- document and archive inventory calculation sheets and background data.

1.6.3 QMS Structure

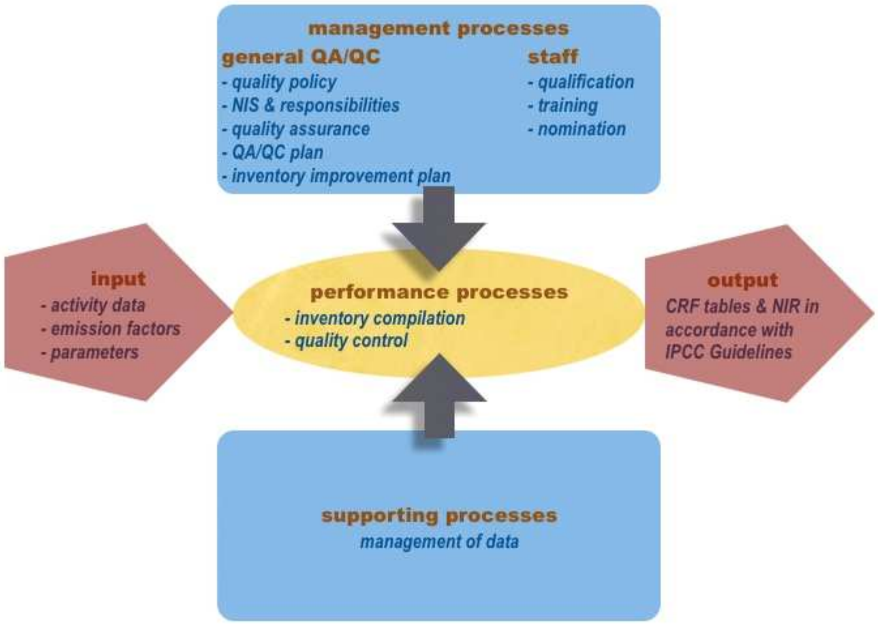
Luxembourg's Quality Management System (QMS) of the GHG Inventory is organised in three layers (Figure 1-4):

a) Performance processes: Performance processes directly concern the compilation of the GHG Inventory. They comprise input data, data acquisition, calculations, and generation of CRF tables and NIR as well as quality control checks and the outcomes of the NIR and CRF-tables.

b) Management processes: Management processes control the system's performance by defining quality objectives, responsibilities, quality assurance procedures, improvement plans and the personnel's qualifications and obligations.

c) Supporting processes: Supporting processes assist the system's performance by providing technical requirements and standards.

Figure 1-4 – QMS structure



1.6.4 Quality Manual

The applied quality manual adopts the structure of the QMS and is divided in management, performance and supporting processes.

For each process, a list of related documents exists with information on content, handling, interval of document check and planned improvement. An extract of the quality manual is given below (Figure 1-5).

Figure 1-5 – Extract of QA/QC Manual

	QA/QC procedure	purpose	document	content	handling	interval of document check
management processes	**quality policy**	basis of the implemented quality management system	quality policy	obligation to prepare and improve a GHG inventory according the demands resulting from UNFCCC, Kyoto protocol and other obligations	the head of administration, NIC and quality manager check validity of quality policy -> adjustment if necessary -> announcement	yearly before kick-off meeting
	general QA/QC	organisation of inventory work	definitions and list of abbreviations	explanation of important terms and abbreviations that are used	NIC and quality manager check validity -> adjustment if necessary	yearly before kick-off meeting
			Luxembourg's National Inventory System	organisation of Luxembourg's National System, organigram, position of QA/QC within the organisation, handling of submission	"Règlement grand-ducal du 1er août 2007 relatif à la mise en place d'un Système d'Inventaire national des émissions de gaz à effet de serre dans le cadre de la Convention-cadre des Nations Unies sur le Changement Climatique" (RGD) dictates handling of submission (AEV -> EIONET, MEV -> UNFCCC); NIC and quality manager check validity -> adjustment if necessary -> announcement	yearly before kick-off meeting
			responsibilities	personnel involved in inventory work (collection of activity data, selection of emission factors and methods, calculation of emissions, data compilation, uncertainties, recalculations, identification of key categories, etc.)	nomination of sector experts and data suppliers according RGD; NIC and quality manager check validity -> adjustment if necessary -> announcement	yearly before kick-off meeting
	personnel		nominations	nominations of sector experts and data suppliers according RGD	nomination by minister of environment; NIC and quality manager check validity -> information of ministry if necessary	yearly before kick-off meeting
			personal file	proof of sector expert's qualification	sector experts complete their personal file	current
	quality assurance	to support and complete quality control measures	internal audit programm	checklist for performance of internal reviews (conformity with IPCCC Guidelines, target-performance comparison)	internal audit of general aspects by quality manager, of sector specific aspects by NIC -> internal audit report -> QA/QC plan	yearly before kick-off meeting
		check of formal aspects	internal audit report	audited sectors, observations, proposed improvements	report prepared by quality manager and NIC -> generation of QA/QC plan	current
		check of applicability & comparisons	external audit report	audited sectors, observations, proposed improvements	report prepared by external persons or organisations -> generation of QA/QC plan	current
			audit list	date, audit character, audited sectors, auditors, hence prepared audit reports and QA/QC plans	auditlist completed by NIC and quality manager	current
			inconsistencies	procedure for handling of inconsistencies (that are detected during compilation of inventory, in internal or external audits)	documenting and archiving of indication of inconsistency (audit report, annotation) -> informing of NIC and quality manager -> entry of proposals for improvement in QA/QC plan	yearly before kick-off meeting
	improvement plan	list of objectives and proposed actions in order to improve inventory's quality	improvement plan	QAQC plan, inventory improvement plan, priority list	result of internal and external audits; documenting of detected inconsistencies or possibilities for improvement in QA/QC plan by NIC and quality manager -> definition of deadlines -> check if objectives have been achieved during the following audits	current
performance processes	**inventory**		inventory timetable	timetable for inventory planning and preparation, sector specific timetable for inventory planning and preparation, QAQC timetable, submission deadlines	NIC, quality manager and sector experts check validity -> adjustment if necessary -> announcement per mail	yearly before kick-off meeting
			calculation sheets	calculated emissions; information on activity data, data suppliers (QA/QC), emission factors, calculation methods and special events; information on completeness, revisions and planned improvements of emission data	sector experts complete their calculation sheets -> transfer to NIC before deadline; check of document by NIC and quality manager; check of data content by sector expert	yearly before kick-off meeting
			NIR and crf-tables	national greenhouse gas inventory	sector experts submit calculation sheets to NIC before deadline -> NIC generates crf-tables and compiles NIR -> submission of crf-tables and NIR to EU and UNFCCC	current according the deadlines
	quality control	activities to assess and maintain the quality of the inventory being compiled	sector specific checklists validation and verification	Accuracy checks on data acquisition and calculations, verification of activity data, emission factors and methods	performance by sector experts before submission; completion of checklists; archiving of checks; transmission of completed checklists in common with NIR data to NIC	yearly before kick-off meeting
			checklist data supplier	validation of data that are submitted by plant operators and other organisations	performance by data supporter before submission; check and archiving by sector expert	yearly before kick-off meeting
supporting processes	**data managemen**	definition of data naming and archiving	data flow	cooperation between the competent authorities and organisations; exchange and archiving of data and information	sector experts calculate emissions and perform data validation checks -> submission of calculations to NIC -> NIC validates methods, activity data and emission factors, generates crf-tables and compiles NIR; NIC and quality manager perform internal audit on NIR compilation -> generation of a QA/QC plan including proposed improvements -> information of sector experts and implementation of improvements	yearly before kick-off meeting
			data management on CIRCA	instruction for data naming and archiving	NIC designates access authorisation	yearly before kick-off meeting

Sources: SEG Umwelt-Service GmbH and Environment Agency.

1.6.5 Inventory Timetable

The inventory timetable gives several schedules to control the performance of inventory compilation, quality control and quality assurance procedures, implementation of inventory improvements and inventory publication (see Table 1-2 in Section 1.2.2).

In addition, there are summaries of deadlines regarding EU and UNFCCC submissions.

1.6.5.1 Timetable for inventory planning and preparation

This schedule refers to general inventory work:

- Yearly meetings of the inventory work group and the decision making body
- Key category analysis
- Uncertainty analysis
- Generation of CRF-tables
- NIR preparation and finalisation
- NIR and CRF submission
- Publication and archiving of NIR
- Consideration and implementation of EU review recommendations
- Consideration and implementation of UNFCCC review recommendations
- Internal and external training
- Documentation and archiving

1.6.5.2 Sector specific timetable for inventory planning and preparation

This schedule refers to sector specific compilation work and quality control checks:

- Collection of activity data, emission factors and other parameters
- Calculation of emissions and removals
- Quality check of data, comparison with previous years, documentation of calculations and assumptions
- Uncertainty analysis
- Completion of checklists and other QC activities
- Documentation and archiving

1.6.5.3 QA/QC timetable

This schedule especially refers to QA procedures:

- Internal audit
- Implementation of internal review recommendations
- Yearly meetings of the inventory work group and the decision making body
- QA/QC training for the National Inventory Compiler and the sector experts.

1.6.6 Quality Control and Quality Assurance procedures

The first steps to implement quality control and quality assurance procedures have already been undertaken but need further improvement. The current status and planned improvements are described in the following sub-sections.

Figure 1-6 – QA/QC Procedures

does NOT require knowledge of the emission source category	requires knowledge of the emission source category
general	source specific
QC procedures sector experts (1st party) performed throughout preparation of inventory	
TIER 1	**TIER 2**
data validation, calculation sheet (check of formal aspects)	preparation of NIR, comparison with Guidelines (check of applicability, comparisons)
QA procedures quality manager (2nd or 3rd party; staff not directly involved, preferably independent) performed after inventory work has finished	
TIER 1 basic, before submission	
	Internal audit / EU 'Initial check' **(Expert Peer Review)**
	evaluate if TIER2 QC is effectively performed (check if methodologies are applicable)
TIER 2 extensive	
System audit by Umweltbundesamt (Audit)	**ICR by UNFCCC (Expert Peer Review)**
evaluate if TIER 2 QC is effectively performed	evaluate if TIER 2 QC is effectively performed (Check if methodologies are applicable)

Sources: Umweltbundesamt Austria, SEG Umwelt-Service GmbH and Environment Agency.

1.6.6.1 Quality Control procedures

The following Quality Control procedures are conducted:

a) Yearly meeting of the decision making body (the decision making body consists of the head of the AEV, the National Inventory Compiler and the quality manager) in order to appoint responsibilities, priorities and schedules for inventory work.

b) Checklists for data supplier that have to be completed by external suppliers of input data in order to assure the reliability of reported data.

c) Checklists for validation of data that have to be completed by sector experts until data are transmitted to the National Inventory Compiler. An example of a data validation checklist is given in Figure 1-7.

Figure 1-7 – Data Validation Checklist

Data:				1990 - 2xxx														
Source:	CRF	XXX		Snap	XX XX													
	Activity data			check done			Emission factor			check done			Emissions			check done		
Greenhouse gas	CO2	CH4	N2O	Remarks	Date	Person	CO2	CH4	N2O	Remarks	Date	Person	CO2	CH4	N2O	Remarks	Date	Person
Content check																		
Trend checks																		
For each category, current inventory estimates should be compared to previous estimates, if available. If there are significant changes or departures from expected trends, re-check estimates and explain any differences																		
Data plausible in comparison to other references																		
Check time series consistency																		
For each category check input data for temporal consistency in time series																		
Check methodological and data changes resulting in recalculations																		
Check that the effects of mitigation activities have been appropriately reflected in time series calculations																		
Check completeness																		
Confirm that estimates are reported for all categories and for all years from the appropriate base year to the period of the current inventory																		
For subcategories, confirm that entire category is being covered																		
Provide clear definition of "Other" type categories																		
Check that known data gaps that result in incomplete estimates are documented, including a qualitative evaluation of the importance of the estimate in relation to total emissions																		
Uncertainty estimation of data existent																		
data relying on a legal reporting commitment																		
Formal check																		
Collection of data is understandable																		
Check that assumptions and criteria for the selection of data are documented																		
Assumptions and criteria for the selection of data are documented																		
Cross-check descriptions of activity data, emission factors and other estimation parameters with information on categories and ensure that these are properly recorded and archived																		
Check for transcription errors in data input and reference																		
data correctly entered and transcribed																		
Confirm that bibliographical data references are properly cited in the internal documentation																		
Cross-check a sample of data from each source category (either measurements or parameters used in calculations) for transcription errors																		
Accurate data aggregation and correctness of calculations																		
Parameters and units are correctly recorded																		
Data fields are properly labelled																		
Data transmission of intermediate result is correct																		
Check that parameters and units are correctly recordedand that appropriate conversion factors are used																		
Units are properly labelled and correctly carried through from beginning to end of calculations																		
Conversion factors respectively temporal and spatial adjustment factors are correct																		
Data path and data coherence are understandable																		
Consistency given for the multiple use of data																		
Archiving of data and records ensured																		
Emissions complete																		
Uncertainty estimation of emissions existent																		
emission measurements in compliance with international accredited standards																		

	Uncertainties			check done		
Greenhouse gas	CO2	CH4	N2O	Remarks	Date	Person
Content check						
Check that uncertainties in emissions and removals are estimated and calculated correctly						
Check that qualifications of individuals providing expert judgement for uncertainty estimates are appropriate						
Check that qualifications, assumptions and expert judgements are recorded						
Formal check						
Designation of uncertainties is understandable						
Uncertainties complete						
documentation of fundamental assumption concerning expert judgement						
Archiving of data and records ensured						

Sources: Umweltbundesamt Austria, SEG Umwelt-Service GmbH and Environment Agency.

Checks for validation of data include:

- o Checks of activity data (trend checks, time series consistency, completeness, check of assumptions and criteria for activity data, check for transcription errors in data input and reference)
- o Checks of emission factors (trend checks, time series consistency, completeness, check of correct recording of units and the use of appropriate conversion factors, check of documentation of assumptions and criteria for the selection of emission factors, check for transcription errors in data input and reference)
- o Checks of emissions (trend checks, time series consistency, completeness, check of documentation of assumptions and criteria for emissions, check for transcription errors in data input and reference, check of correct recording of units and the use of appropriate conversion factors)
- o Check of uncertainties (check of correct calculation and estimation of uncertainties in emissions and removals).

d) Checklists for verification of methods, activity data and emission factors that have to be completed by sector experts.

e) Checklist for the monitoring of internal and external reviews that has to be completed by the quality manager.

1.6.6.2 Quality Assurance procedures

The following Quality Assurance procedures are conducted:

- Internal audit during NIR preparation time performed by the quality manager, the National Inventory Compiler and a consultant from the "Umweltbundesamt Wien". The internal review analyses every sector as well as the QMS system and checks:
    - o whether inventory work and the inventory comply with Revised 1996 IPCC Guidelines, Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories and Good Practice Guidance for Land Use, Land Use Change and Forestry
    - o whether data acquisition, calculation, referencing and archiving is handled according to the defined methods
    - o whether there are enough resources for inventory work
    - o whether relevant data are available and if the reliability of external data is guaranteed
    - o whether the QMS system needs improvement
    - o whether recommendations of EU reviews, UNFCCC reviews and previous internal audits have been considered and implemented.
- QA/QC training for the sector experts and the National Inventory Compiler during execution of the internal audit.
- Support by inventory experts from the "Umweltbundesamt Wien".
- External audits conducted by experts who provide support for inventory work, EU or UNFCCC.

1.6.6.3 Improvement plan

The results from internal and external audits are merged in the improvement plan. This plan lists the relevant sector, recommendations for improvement, priorities, responsibilities, deadlines and gives opportunity for attest.

The improvement plan is segmented in a QA/QC plan, that contains recommendations for the improvement of the QMS and an inventory improvement plan that contains recommendations for inventory improvement.

The decision making body prioritises the recommended improvements and cares for associated resources.

1.6.6.4 Planned improvements

The following QMS improvements shall be implemented in 2014 and the following years:

- Strengthening the implementation of the QMS in general
- Improvement of QC procedures in the LULUCF sector
- Strengthening the implementation of QAQC procedures in KP-LULUCF
- Development of the four-eyes principle in inventory work
- Continuance in QA/QC training of NIC and sector experts
- Implementation of 2006 IPCC Guidelines

1.6.7 Archiving and documentation

Within the inventory system, a system for transparent documentation of inventory data and related information (special circumstances, assumptions *etc.*) is implemented. Archiving takes place on the server "Circalux" within the folder "Inventaires gaz à effet de serre"[30]. The data is secure for at least fifteen years.

As a principle every file shall be named clearly, shall be write/delete protected and supply relevant information concerning validity in the footer.

1.6.8 Treatment of confidentiality issues

In this submission, there is no data reported using the notation key C (confidential).

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30 https://circalux.etat.lu/Members/irc/public/invges/home (only for members)

1.7 General uncertainty evaluation, including data on the overall uncertainty for the inventory totals

Uncertainty estimates are an essential element of a complete inventory of greenhouse gas emissions and removals and requires a detailed understanding of the uncertainties of the respective input parameters. They should be derived for both the national level and the trend estimate, as well as for the component parts such as emission factors, activity data and other estimation parameters for each category. [31] Principally, two different TIER for the estimation of combined uncertainties are presented in the IPCC GPG: TIER 1 uses simple error propagation equations, while TIER 2 uses Monte Carlo.

TIER 1 is based upon error propagation and is used to estimate uncertainty in individual categories, in the inventory as a whole, and in trends between a year of interest and a base year. The key assumptions, requirements, and procedures are described here. TIER 1 should be implemented using Table 3.2 of the IPCC Guidelines for National Greenhouse Gas Inventories (2006).

The TIER 2 is based on a Monte Carlo analysis, which is suitable for detailed category-by-category assessment of uncertainty, particularly where uncertainties are large, distribution is non-normal, the algorithms are complex functions and/or there are correlations between some of the activity sets, emissions factors, or both.

1.7.1 GHG inventory

In autumn 2011, the Environment Agency contracted a second time Austrian Research Centers GmbH - ARC to perform a detailed uncertainty analysis of Luxembourg's GHG inventory. This study was an update of the study 'Uncertainty analysis of Luxembourg's GHG inventory 2007. As there have been major revisions to Luxembourg's inventory, it was worthwhile to revisit the calculations performed in 2007. It is worth noting that the study itself is based on data and information submitted in CRF 2011v1.3 and NIR 2011, however, the results of the study have been implemented in the inventory submitted as CRF 2014v1.4. National information or at least national expert knowledge directly from the stage of inventory development was used for the assessment of uncertainties.

For submission 2017v1.2, only a Tier 1 uncertainty analysis has been carried out. As important methodological changes have occurred in several sectors since the last Tier 2 uncertainty analysis I 2011, a Tier 2 analysis is currently under preparation.

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[31] 2000 IPCC GPG – Chapter UNCERTAINTIES

1.7.1.1 Results using the Tier 1 (error propagation) approach

The input parameters and the results (level and trend uncertainties, with and without LULUCF) of the error propagation approach are presented in Table 1-11. The overall level uncertainty as well as trend uncertainty is being derived as the square root of the squares of the respective contributions.

The TIER 1 approach including LULUCF suggests an overall level uncertainty of 3.90% and a trend uncertainty of 4.53%, and the TIER 1 approach excluding LULUCF suggests an overall level uncertainty of 2.75% and a trend uncertainty of 3.07% (Table 1-11).

Compared to the results of other countries, level and trend uncertainties in Luxembourg are on the lower end of the range. This is plausible, as the situation in Luxembourg is characterized by high energy consumption and emission density, compared to other countries. With respect to GHG emissions, energy data are among the best known, and also CO_2 emission factors are much better understood (can be derived from material balances) than emission factors of CH_4 or N_2O. The fact that, in the total inventory, N_2O and CH_4 are less pronounced at the same time leads to a structurally lower uncertainty.

1.7.1.2 Tier 2 approach

The TIER 2 method is based on a Monte Carlo analysis, which is suitable for detailed category-by-category assessment of uncertainty, particularly where uncertainties are large, distribution is non-normal, the algorithms are complex functions and/or there are correlations between some of the activity sets, emissions factors, or both.

The above described study from 2011 on the uncertainty assessment of Luxembourg's GHG inventory also covers a Tier 2 analysis. A full description of the Tier 2 uncertainty evaluation from 2011, including the required tables, can be provided upon request. Since important methodological changes have occurred in several sectors, a Tier 2 uncertainty analysis is currently under preparation.

1.7.1.3 Scope for improvement

Compared to other countries, the uncertainty of the Luxembourg GHG inventory is quite small already. Still the potential exists to even further improve, as the share of (well understood) emissions from combustion sources is particularly large in the case of Luxembourg, and thus the highly uncertain area-related contributors to GHG inventories play a less important role.

Nevertheless, for Luxembourg like for many other countries where these features have been investigated, the emissions of N_2O from soils and the uptake/release of CO_2 from LULUCF are dominant factors to the uncertainty of the national GHG inventory. It is thus useful to focus on these parameters in an evaluation of possible improvements. By contrast, a scenario analysis carried out in 2011 indicated that further effort on another poorly understood emission source, the release of F-gases, will not be decisive for overall uncertainty in any case and thus need not be prioritized.

Opportunities may actually exist to provide the improvements needed to just these sectors which have been identified the major contributors to uncertainty. In the case of LULUCF, national activities that provide an update to the national forest inventory should be utilized also for the GHG inventory in order to remove major obstacles to data quality also affecting uncertainty. Moreover, close observation should be given to developments on validation of the currently used soil N_2O emission factors. Such validation exercises might provide a closure of the error margins.

Table 1-11 – Input parameters and results of the Tier 1 uncertainty analysis.

IPCC category/Group	Gas	Base year emissions or removals	Year x emissions or removals	Activity data uncertainty (1)	Emission factor / estimation parameter uncertainty (1)	Combined uncertainty	Contribution to variance by category in year x	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty (2)	Uncertainty in trend in national emissions introduced by activity data uncertainty (3)	Uncertainty introduced into the trend in total national emissions	Comments (optional)
		Gg CO2 equivalent	Gg CO2 equivalent	%	%								
		input data	input data	input data Note A	input data Note A	$\sqrt{E^2+F^2}$	$\frac{(G \bullet D)^2}{(\sum D)^2}$	Note B	$\left\lvert \frac{D}{\sum C} \right\rvert$	I*F Note C	J*E*sqrt(2) Note D	K^2 + L^2	
1A Stationary Combustion - Gaseous Fuels	CO2	1035.80	1828.10	2%	1%	0.0206	0.0000	0.0771	0.1444	0.0004	0.0041	1.68E-05	
1A Stationary Combustion - Gaseous Fuels	CH4	1.04	2.15	2%	50%	0.5004	0.0000	0.0001	0.0002	0.0001	0.0000	2.64E-09	
1A Stationary Combustion - Gaseous Fuels	N2O	0.53	0.96	2%	50%	0.5004	0.0000	0.0000	0.0001	0.0000	0.0000	4.27E-10	
1A Stationary Combustion - Liquid Fuels	CO2	1274.51	1022.89	2%	1%	0.0206	0.0000	0.0020	0.0808	0.0000	0.0023	5.22E-06	
1A Stationary Combustion - Liquid Fuels	CH4	3.48	2.72	2%	50%	0.5004	0.0000	0.0000	0.0002	0.0000	0.0000	6.98E-11	
1A Stationary Combustion - Liquid Fuels	N2O	14.85	12.41	2%	50%	0.5004	0.0000	0.0000	0.0010	0.0000	0.0000	8.32E-10	
1A Stationary Combustion - Other Fuels	CO2	33.29	129.35	8%	20%	0.2154	0.0000	0.0081	0.0102	0.0016	0.0012	3.93E-06	
1A Stationary Combustion - Other Fuels	CH4	0.25	1.08	8%	50%	0.5064	0.0000	0.0001	0.0001	0.0000	0.0000	1.29E-09	
1A Stationary Combustion - Other Fuels	N2O	0.40	1.72	8%	50%	0.5064	0.0000	0.0001	0.0001	0.0001	0.0000	3.26E-09	
1A Stationary Combustion - Biomass	CH4	5.50	8.10	7%	50%	0.5049	0.0000	0.0003	0.0006	0.0001	0.0001	2.40E-08	
1A Stationary Combustion - Biomass	N2O	1.81	3.55	7%	60%	0.6041	0.0000	0.0002	0.0003	0.0001	0.0000	1.03E-08	
1A Stationary Combustion - Solid Fuels	CO2	5317.44	165.41	1%	3%	0.0316	0.0000	0.3310	0.0131	0.0099	0.0002	9.87E-05	
1A Stationary Combustion - Solid Fuels	CH4	5.40	0.62	1%	50%	0.5001	0.0000	0.0003	0.0000	0.0002	0.0000	2.28E-08	
1A Stationary Combustion - Solid Fuels	N2O	5.94	0.78	1%	50%	0.5001	0.0000	0.0003	0.0001	0.0002	0.0000	2.63E-08	
1A3a Transport - Civil Aviation	CO2	0.21	0.60	10%	5%	0.1118	0.0000	0.0000	0.0000	0.0000	0.0000	4.84E-11	
1A3a Transport - Civil Aviation	CH4	0.00	0.00	10%	100%	1.0050	0.0000	0.0000	0.0000	0.0000	0.0000	3.78E-17	
1A3a Transport - Civil Aviation	N2O	0.00	0.01	10%	150%	1.5033	0.0000	0.0000	0.0000	0.0000	0.0000	1.89E-13	

IPCC category/Group	Gas	Base year emissions or removals	Year x emissions or removals	Activity data uncertainty (1)	Emission factor / estimation parameter uncertainty (1)	Combined uncertainty	Contribution to variance by category in year x	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty (2)	Uncertainty in trend in national emissions introduced by activity data uncertainty (3)	Uncertainty introduced into the trend in total national emissions	Comments (optional)
		Gg CO2 equivalent	Gg CO2 equivalent	%	%								
		input data	input data	input data Note A	input data Note A	$\sqrt{E^2+F^2}$	$\frac{(G\bullet D)^2}{(\sum D)^2}$	Note B	$\left\|\frac{D}{\sum C}\right\|$	I*F Note C	J*E*sqrt(2) Note D	K^2 + L^2	
1A3b - Road Transportation - Diesel Oil	CO2	1342.84	4723.19	2%	2%	0.0283	0.0002	0.2856	0.3731	0.0057	0.0106	1.44E-04	
1A3b - Road Transportation - Diesel Oil	CH4	0.48	0.25	2%	20%	0.2010	0.0000	0.0000	0.0000	0.0000	0.0000	5.84E-12	
1A3b - Road Transportation - Diesel Oil	N2O	2.65	42.81	2%	20%	0.2010	0.0000	0.0032	0.0034	0.0006	0.0001	4.21E-07	
1A3b - Road Transportation - Gasoline	CO2	1259.98	875.66	2%	2%	0.0283	0.0000	0.0127	0.0692	0.0003	0.0020	3.89E-06	
1A3b - Road Transportation - Gasoline	CH4	10.93	1.73	2%	20%	0.2010	0.0000	0.0006	0.0001	0.0001	0.0000	1.32E-08	
1A3b - Road Transportation - Gasoline	N2O	13.21	2.78	2%	20%	0.2010	0.0000	0.0006	0.0002	0.0001	0.0000	1.63E-08	
1A3b - Road Transportation - LPG	CO2	11.34	2.02	2%	2%	0.0283	0.0000	0.0006	0.0002	0.0000	0.0000	1.54E-10	
1A3b - Road Transportation - LPG	CH4	0.09	0.00	2%	40%	0.4005	0.0000	0.0000	0.0000	0.0000	0.0000	4.61E-12	
1A3b - Road Transportation - LPG	N2O	0.13	0.01	2%	100%	1.0002	0.0000	0.0000	0.0000	0.0000	0.0000	5.76E-11	
1A3c - Railways	CO2	24.72	6.95	2%	2%	0.0283	0.0000	0.0011	0.0005	0.0000	0.0000	6.88E-10	
1A3c - Railways	CH4	0.03	0.01	2%	150%	1.5001	0.0000	0.0000	0.0000	0.0000	0.0000	4.96E-12	
1A3c - Railways	N2O	2.85	0.80	2%	200%	2.0001	0.0000	0.0001	0.0001	0.0002	0.0000	5.95E-08	
1A3d - Navigation	CO2	1.28	1.08	2%	2%	0.0283	0.0000	0.0000	0.0001	0.0000	0.0000	5.87E-12	
1A3d - Navigation	CH4	0.01	0.00	2%	50%	0.5004	0.0000	0.0000	0.0000	0.0000	0.0000	4.69E-15	
1A3d - Navigation	N2O	0.01	0.01	2%	140%	1.4001	0.0000	0.0000	0.0000	0.0000	0.0000	8.30E-16	
1B2b - Fugitive Emission from Natural Gas	CO2	0.03	0.05	2%	100%	1.0002	0.0000	0.0000	0.0000	0.0000	0.0000	3.75E-12	
1B2b - Fugitive Emission from Natural Gas	CH4	19.36	34.55	2%	100%	1.0002	0.0000	0.0015	0.0027	0.0015	0.0001	2.17E-06	
2A1 - Cement Production	CO2	569.88	321.89	1%	3%	0.0269	0.0000	0.0116	0.0254	0.0003	0.0004	2.13E-07	
2A3 - Glass Production	CO2	53.57	59.74	2%	10%	0.1020	0.0000	0.0012	0.0047	0.0001	0.0001	3.32E-08	
2C1 - Iron & Steel Production	CO2	984.91	122.80	5%	5%	0.0707	0.0000	0.0543	0.0097	0.0027	0.0007	7.83E-06	
2D1 - Lubricant use	CO2	6.20	4.56	5%	50%	0.5025	0.0000	0.0000	0.0004	0.0000	0.0000	1.11E-09	
2D2 Paraffin wax use	CO2	0.21	1.54	5%	100%	1.0012	0.0000	0.0001	0.0001	0.0001	0.0000	1.17E-08	
2D3 - solvent use	CO2	15.41	13.74	50%	50%	0.7071	0.0000	0.0001	0.0011	0.0000	0.0008	5.91E-07	
2D3 - urea-based catalysts	CO2	0.00	9.70	20%	5%	0.2062	0.0000	0.0008	0.0008	0.0000	0.0002	4.84E-08	
2F - Product Uses as Substitutes for ODS	F-gases	18.31	66.02	30%	20%	0.3606	0.0000	0.0040	0.0052	0.0008	0.0022	5.54E-06	
2G - Other Product Manufacture and Use	F-gases	1.39	8.89	30%	20%	0.3606	0.0000	0.0006	0.0007	0.0001	0.0003	1.04E-07	
2G - Other Product Manufacture and Use	N2O	7.58	3.48	20%	20%	0.2828	0.0000	0.0002	0.0003	0.0000	0.0001	7.94E-09	

IPCC category/Group	Gas	Base year emissions or removals	Year x emissions or removals	Activity data uncertainty (1)	Emission factor / estimation parameter uncertainty (1)	Combined uncertainty	Contribution to variance by category in year x	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty (2)	Uncertainty in trend in national emissions introduced by activity data uncertainty (3)	Uncertainty introduced into the trend in total national emissions	Comments (optional)
		Gg CO2 equivalent	Gg CO2 equivalent	%	%								
		input data	input data	input data Note A	input data Note A	$\sqrt{E^2+F^2}$	$\frac{(G \bullet D)^2}{(\sum D)^2}$	Note B	$\left\|\frac{D}{\sum C}\right\|$	I*F Note C	J*E*sqrt(2) Note D	K^2 + L^2	
3 - Agriculture	CO2	428.44	420.87	54%	0%	0.5400	0.0005	0.0054	0.0333	0.0000	0.0254	6.45E-04	total sector uncertainty
3 - Agriculture	CH4	1.78	2.31	4%	0%	0.0400	0.0000	0.0001	0.0002	0.0000	0.0000	1.07E-10	total sector uncertainty
3 - Agriculture	N2O	2.83	3.58	121%	0%	1.2100	0.0000	0.0001	0.0003	0.0000	0.0005	2.34E-07	total sector uncertainty
4 - Land Use, Land-Use Change and Forestry	CO2, N2O	64.87	404.03	74%	0%	0.7400	0.0008	0.0277	0.0319	0.0000	0.0334	1.12E-03	total sector uncertainty
5A - Solid Waste disposal on Land	CH4	95.76	53.17	8%	42%	0.4276	0.0000	0.0020	0.0042	0.0008	0.0005	9.47E-07	
5B - Biological treatment of solid waste	CH4	0.00	20.75	5%	50%	0.5025	0.0000	0.0016	0.0016	0.0008	0.0001	6.85E-07	
5B - Biological treatment of solid waste	N2O	0.00	10.11	5%	100%	1.0012	0.0000	0.0008	0.0008	0.0008	0.0001	6.42E-07	
5D - Wastewater treatment and discharge	CH4	7.30	3.50	10%	50%	0.5099	0.0000	0.0002	0.0003	0.0001	0.0000	1.13E-08	
5D - Wastewater treatment and discharge	N2O	8.86	7.09	10%	50%	0.5099	0.0000	0.0000	0.0006	0.0000	0.0001	6.33E-09	
Total Uncertainties excluding LULUCF						Uncertainty in total inventory excl. LULUCF:	2.75%				Trend uncertainty excl. LULUCF:	3.07%	
Total Uncertainties including LULUCF						Uncertainty in total inventory incl. LULUCF:	3.90%				Trend uncertainty incl. LULUCF:	4.53%	

1.7.2 KP-LULUCF inventory

Please refer to section 11.3.1.5 for uncertainties of emissions/removals of the ARD units.

1.8 General assessment of completeness

1.8.1 GHG inventory

CRF table 9 on completeness has been filled for every reported year 1990 to 2015. It is expected that this table recapitulates all the explanations given for the notation keys reported in Luxembourg's GHG inventory for a given year since all the checks included in CRF Reporter were passed successfully by submission 2017v1.2. Hence, if missing information is encountered in CRF table 9 for some years, this is not due to a lack of explanations from the side of Luxembourg, but well due to conversion problems in CRF Reporter when the CRF tables are created.

In this section, some additional information is presented. An assessment of completeness for each CRF sector is given in the sector overview part of each of the sector chapters.

1.8.1.1 Sources and sinks

All sources and sinks included in the IPCC Guidelines are covered. With regards to LULUCF, this submission contains new estimations for LULUCF, the three main sub-categories now being covered as well as the sub-categories wetlands, settlements and other lands, which were not estimated in the previous submission.

1.8.1.2 Gases

Both direct GHGs and indirect GHGs – NO_x, CO, NMVOCs – and SO_2 are covered by Luxembourg's inventory.

1.8.1.3 Geographic coverage

The geographic coverage is complete. There is no part of the national territory not covered by the inventory.

1.8.1.4 Notation keys

The sources and sinks not considered in the inventory, but included in the IPCC Guidelines, are clearly indicated. The reasons for such exclusions are explained. In addition, the notation keys presented below are used to fill in the blanks in all the CRF tables.

Notation keys used in the NIR are consistent with those reported in the CRF tables. Notation keys used are those described on page 12 of document FCCC/CP/2013/10/Add.3 dated 22nd November 2013.

Allocations to categories may differ from Party to Party. The main reasons for different category allocations are different allocations in national statistics, insufficient information in national statistics and/or national methods, and the impossibility to disaggregate emission declarations.

IE (included elsewhere)
The notation key IE is used for emissions by sources and removals by sinks of GHG that have been estimated but included elsewhere in the inventory instead of the expected source/sink category. Where IE is used in the inventory, CRF table 9 indicates where (in the inventory) these emissions or removals have been included. Such deviation from the expected category is also explained.

NE (not estimated)
The notation key NE is used for existing emissions by sources and removals by sinks of GHG which have not been estimated. Where NE is used in an inventory for emissions or removals, CRF table 9 indicates why emissions or removals have not been estimated.

NA (not applicable)
The notation key NA is used for activities or processes in a given source/sink category that do not produce emissions or lead to removals of a specific gas.

NO (not occurring)
The notation key NO is used for activities or processes in a given source/sink category that do not occur within Luxembourg.

C (confidential)
The notation key C is used for emissions which could lead to the disclosure of confidential information if reported at the most disaggregated level. In this case, a minimum of aggregation is required to protect business information.

1.8.2 KP-LULUCF inventory

All mandatory activities according to Article 3.3 and Article 3.4 of the Kyoto Protocol are estimated. Luxembourg did not elect Article 3.4 activities, such as Cropland Management, Grazing land Management, Revegetation, Wetland Drainage and Rewetting. Forest management activities were estimated, as these are mandatory for the second commitment period.

2 Trends in Greenhouse Gas Emissions

According to the Kyoto Protocol, Luxembourg's GHG emissions had to be 8% below base year emissions during the five-year commitment period from 2008 to 2012. The European Community and its Member States also had a common reduction target of 8%, which they decided to achieve jointly. In April 2002, the Council of the European Union has adopted a decision, the so-called "burden sharing agreement", which includes reduction targets for each Member State. Luxembourg agreed to reduce its GHG emissions for 2008–2012 by 28% compared to the base year emissions level. The second commitment period bridges the gap between the end of the 1st Kyoto period and the start of the new global agreement in 2020. Luxembourg, together with 27 other EU member states and Iceland, has agreed to make further cuts by 20% of GHG emissions compared to 1990 (Doha Agreement).

When estimating GHG emission composition and trends in Luxembourg, one should keep in mind that the IPCC methodology used for compiling GHG inventories is raising some peculiar issues for small countries, in particular because of the "territory" or "origin" principle underpinning it. Therefore, in Section 2.1, specific national circumstances are examined. These specific conditions are relating to socio-economic characteristics that have significant effects on Luxembourg's GHG total emissions when applying IPCC accounting rules. This first section is complemented by a discussion of how both the UNFCCC and the Kyoto Protocol are challenging Luxembourg's action with regard to climate change (Section 2.2) and by a general overview of the national circumstances (Section 2.3). Section 2.4 concludes this chapter with an overview of the main developments of and drivers to GHG emissions in Luxembourg since 1990.

2.1 National Circumstances

2.1.1 The Grand-Duchy of Luxembourg

The Grand-Duchy of Luxembourg has been an independent sovereign state since the Treaty of London was signed on 19 April 1839. The country is a **parliamentary democracy** in the form of a **constitutional monarchy** and is the second smallest Member State of the EU-28, after Malta. For many years, it has been characterized by **high economic and demographic growth rates**. The country is **located in the heart of North-Western Europe** and has direct borders with Belgium, Germany and France (Figure 2-1). It is therefore a crossroad for international trade and related transport flows, the most dynamic source of its GHG emissions.

Luxembourg has a territory of 2 586 km². The maximum distance from North to South is some 82 km, from West to East about 57 km (Figure 2-2). In 2015, 85.3% of the total area of Luxembourg was agricultural land and land under forest – with around 51% for agriculture and 35% for forests.

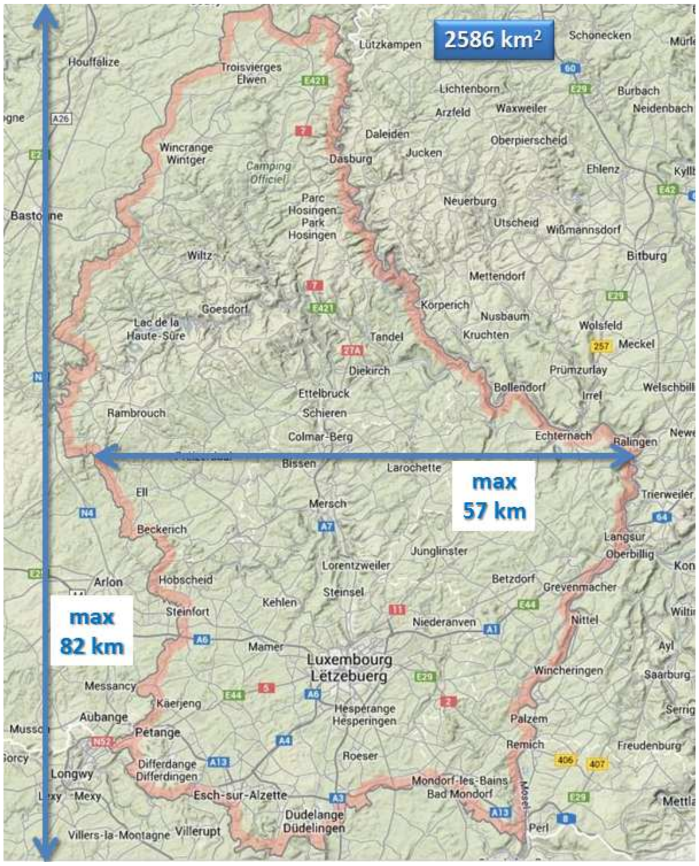
The built-up areas occupied 9.7% of the total surface and land covered by water and transport infrastructure about 5% (Table 2-1 & Figure 2-3).

The North of Luxembourg is a part of the Ardennes and is called "Ösling". Its altitude is at an average of 400 to 500 meters above sea level. The "Ösling" landscape is affected by hills and deep river valleys, as for instance the Sure (Sauer) river. With 560 m, the highest elevation is called the "Kneiff" in Wilwerdange. In the South of Luxembourg lies the rank "Gutland", which belongs to the "Lothringer Stufenland". This area has higher population and industrial densities than "Ösling". The lowest point in the country, called "Spatz" (129 m above sea level), is located at the confluence of the Moselle and the Sure rivers in Wasserbillig. The most important rivers are the Moselle, the Sure, the Our – all three delimiting the border with Germany – and the Alzette.

Figure 2-1 – GEOGRAPHIC LOCATION OF LUXEMBOURG

Source: Google Maps.

Figure 2-2 – LUXEMBOURG SIZE



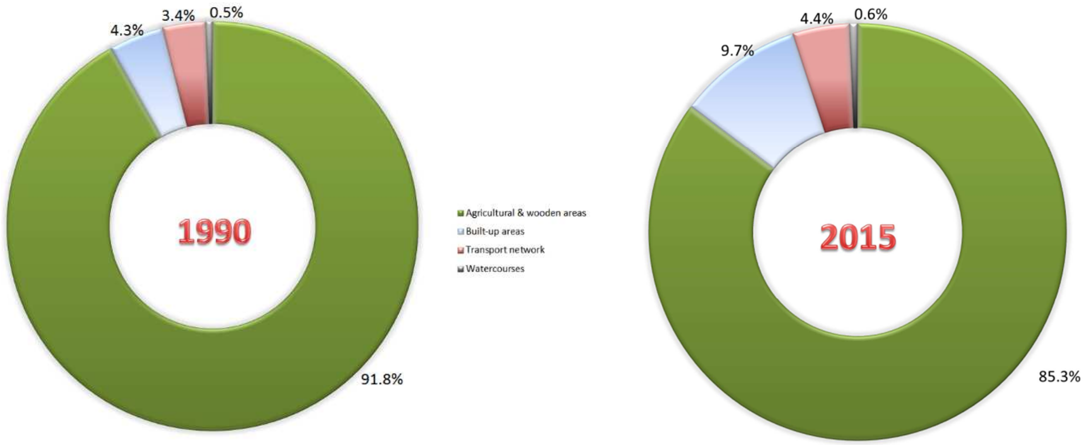
Source: Google Maps.

Table 2-1 – Land use in Luxembourg: 1972-2015

percentages	1972	1990	2000	2005	2010	2015
Total land	100.0	100.0	100.0	100.0	100.0	100.0
Agricultural & wooden area	93.2	91.8	87.4	86.5	85.7	85.3
Built-up area	3.1	4.3	8.1	8.7	9.3	9.7
of which industrial area & other	*n.a.*	*n.a.*	*2.7*	*2.8*	*3.0*	*3.0*
Transport network & sheets of water	3.2	3.4	3.9	4.2	4.4	4.4
Watercourses	0.5	0.5	0.6	0.6	0.6	0.6

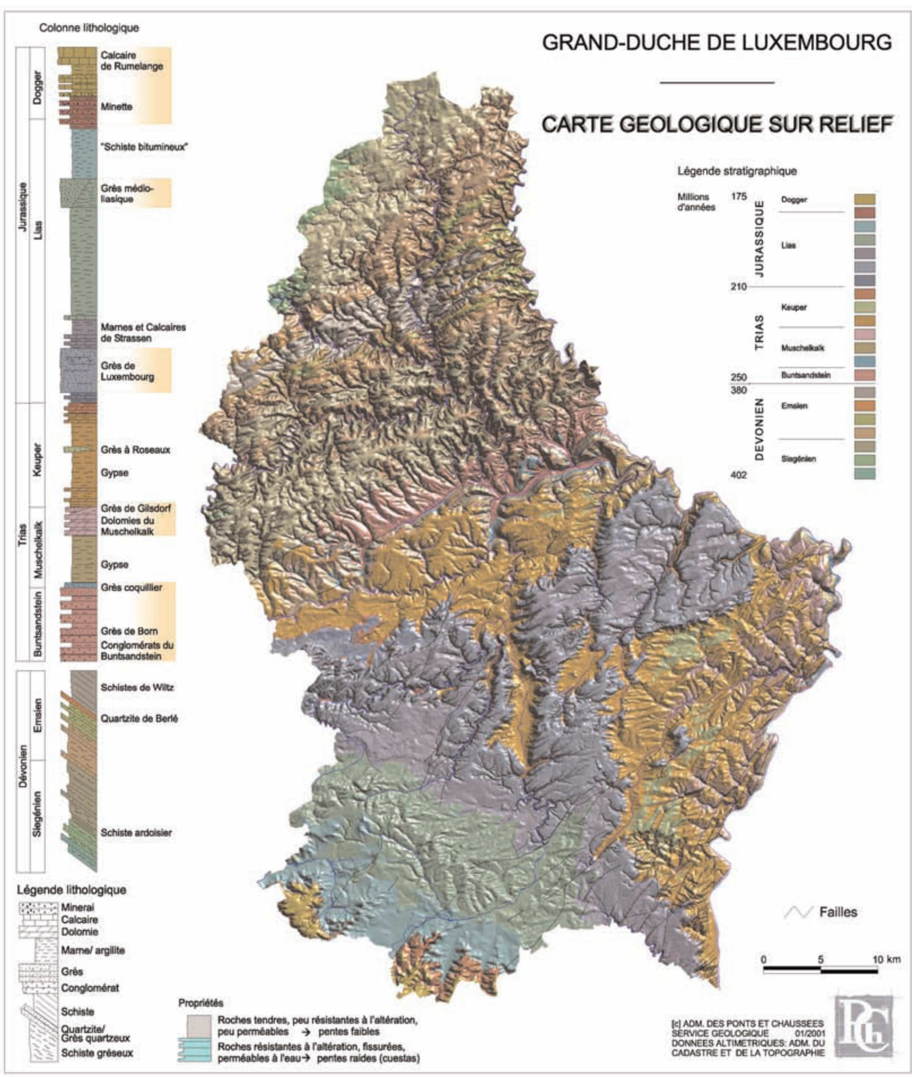
Source: STATEC, Statistical Yearbook, Table A.1101 (updated 29 March 2017): http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=12695&IF_Language=fra&MainTheme=1&FldrName=1

Figure 2-3 – Land use: 1990 & 2015



Source: STATEC, Statistical Yearbook, Table A.1101 (updated 5 April 2016): http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=12695&IF_Language=fra&MainTheme=1&FldrName=1

Figure 2-4 – Geological map of Luxembourg's territory



Source: STATEC, *Annuaire statistique du Luxembourg 2012*, page 39: http://www.statistiques.public.lu/fr/publications/series/annuaire-stat-lux/index.html.

2.1.2 Climate [32]

2.1.2.1 Situation: an increasing average air temperature during the last decades

The climate in Luxembourg can be characterized as a **moderate oceanic Western European climate** with mild winters and comfortable summers.

As shown by the long-term annual means (WMO reference period from 1971 to 2000) measured at the Findel-Airport meteorological station (Table 2-2),[33] temperatures have an unimodal distribution, with the lowest long-term mean values occurring during January (0.6°C – was 0.0°C for the period 1961-1990) and the highest air temperature in July (17.5°C – was 16.9°C for the period 1961-1990). Absolute minimum and maximum air temperatures ever recorded were -20.2°C (2 February 1956) and 37.9°C (8 and 12 August 2003).

According to definitions for GHG reporting, **Luxembourg is situated in a cool climate region** since its annual average air temperature is below 15°C: 8.7°C for the reference period 1971 to 2000 and 9.2°C for the reference period 1981 to 2010 (see Table 2-2).[34]

Climate conditions have significant impacts on energy use for heating or cooling purposes. An increase in average air temperature in the forthcoming years could have a positive impact on energy consumption, especially in the residential, commercial and institutional sectors. However, in case of a substantial increase of average air temperatures, an increase in energy consumption related to a more frequent use of air conditioning systems could be expected.

As shown by measures at the Findel-Airport meteorological station, two conclusions can be drawn: firstly, an increase in average air temperature is observed over the last decades; secondly, annual precipitation does not show such clear trends (Table 2-3). Similar observations have been obtained in scientific studies on the climate in Luxembourg.[35] Concerning air temperatures, these studies show a clear positive trend from 1910 up to the 1950s, then about 3 decades of stabilisation, followed by several colder years. From 1990 onwards, annual mean air temperatures measured at the Findel-Airport meteorological station started to increase rather sharply to systematically be over the 1961-1990 mean value (Figure 2-5). Temperature highs have mostly been observed during the last 15-20 years (Figure 2-6).

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32 The text of this Section has been prepared by Pfister, L., Junk, J., Ferrone, A., Hoffmann, L. of the *Centre de Recherche Public-Gabriel Lippmann*.

33 http://www.ana.public.lu/en/meteo/index.html.

34 See also a graphic representation (http://meteolux.lu/fr/produits-et-services).

35 Ries, C. (éditeur) (2005), *Contribution à la climatologie du Luxembourg: analyses historiques, scenarios futurs* in Ferrantia 43, Musée National d'Histoire Naturelle, Luxembourg, 21-84, (http://ps.mnhn.lu/ferrantia/publications/Ferrantia43.pdf);
Pfister, L., Drogue, G., Poirier, C., and Hoffmann, L. (2005), *Evolution du climat et répercussions sur le fonctionnement des hydrosystèmes au Grand-Duché de Luxembourg au cours des 150 dernières années* in Ferrantia 43, Musée National d'Histoire Naturelle, Luxembourg, 85-100, (http://ps.mnhn.lu/ferrantia/publications/Ferrantia43.pdf).

Further analysis of the data suggests that the average air temperature in Luxembourg has increased during the winter seasons, coupled with longer frost-free periods.

With regard to annual precipitation, no clear changes can be detected from the direct measurements (Table 2-3). However, the seasonal distribution of precipitation totals has shown substantial variability through the past 65 years (Figure 2-7). Most of this variability can be attributed to changes in the atmospheric circulation patterns. An increase in westerly atmospheric fluxes during winter months has reportedly been responsible over the past 30 years for significant redistributions of winter rainfall totals. In combination with higher air temperatures, this has led to higher flood frequencies in most national river basins.[36]

Table 2-2 – Long-term mean values (1961-1990 & 1971-2000) of air temperature and precipitation for Findel-Airport station

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average air t° [°C]	0.0	1.1	4.0	7.5	11.8	14.9	16.9	16.4	13.4	9.1	3.8	1.0	**8.3**
	0.6	1.4	4.7	7.7	12.4	15.1	17.5	17.3	13.5	8.9	4.0	1.8	**8.7**
Mean min. air t° [°C]	-2.3	-1.8	0.6	3.3	7.1	10.2	12.0	11.8	9.3	5.7	1.2	-1.3	**4.7**
	-1.8	-1.5	1.2	3.5	7.7	10.5	12.6	12.5	9.5	5.6	1.4	-0.5	**5.1**
Mean max. air t° [°C]	2.3	4.2	8.0	12.1	16.8	19.9	22.0	21.0	18.2	13.0	6.6	3.3	**12.3**
	2.9	4.5	8.7	12.3	17.3	20.0	22.6	22.5	18.1	12.6	6.6	4.0	**12.7**
Mean annual precipitation sum [mm]	71.2	61.7	70.0	61.2	81.2	82.2	68.4	72.3	70.0	74.6	83.2	79.6	**874.4**
	72.1	57.2	66.7	56.6	78.1	79.8	71.6	64.3	71.3	82.0	77.9	84.9	**862.5**

Sources: 1961-1990 – ASTA, *Annuaire météorologique et hydrologique 1990*.
1971-2000 – Aéroport de Luxembourg, Service Météorologique: http://meteolux.lu/fr/produits-et-services.

Table 2-3 – Mean values of air temperature (daily, mean, maximum & minimum) and precipitation for the Findel-Airport station for different time spans and individual years

	1951-1980	1961-1990	1971-2000	1981-2010
Average air temperature [°C]	8.3	8.3	8.7	9.2
Mean minimum air temperature [°C]	4.6	4.7	5.1	5.6
Mean maximum air temperature [°C]	12.3	12.3	12.7	13.1
Mean yearly precipitation sum [mm]	819.6	874.5	862.4	869.9

	1990	2000	2005	2010	2011	2015
Average air temperature [°C]	9.8	10.0	9.6	8.7	10.6	10.4
Mean minimum air temperature [°C]	6.0	6.5	*n.a.*	5.0	6.6	6.3
Mean maximum air temperature [°C]	13.8	13.8	*n.a.*	12.4	14.8	13.8
Mean yearly precipitation sum [mm]	1020.5	1036.4	718.2	918.5	704.0	604.0

Sources: ASTA, *Atlas hydro-climatologique du Grand-Duché de Luxembourg 2009* and Findel-Airport station (SMA);
Various sources from the Aéroport de Luxembourg, Service Météorologique: http://meteolux.lu/fr/produits-et-services.

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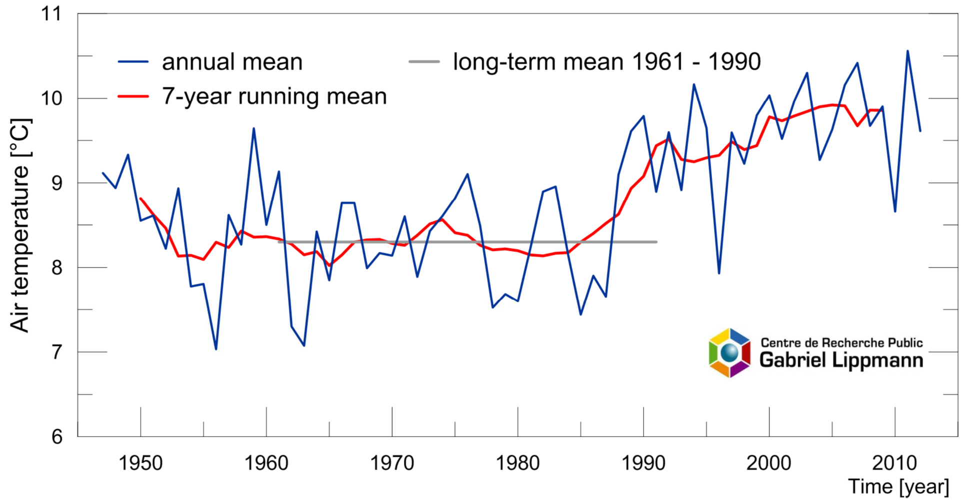
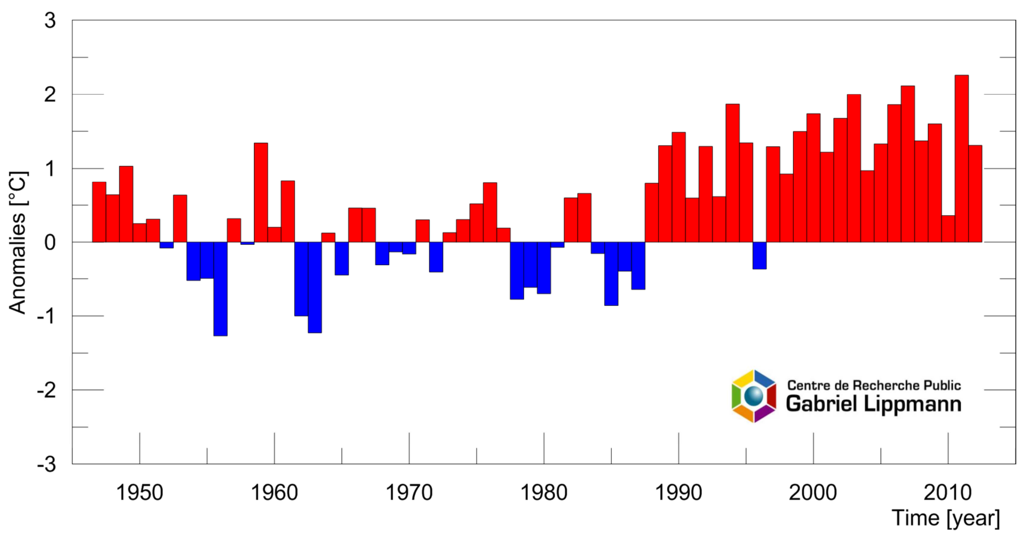
36 Pfister, L., Hoffmann, L., and Humbert, J. (2000), *Recent Trends in Rainfall-Runoff Characteristics in the Alzette River Basin, Luxembourg* in Climatic Change, volume 45, Springer Netherlands, 323-337.
Pfister, L., Drogue, G., El Idrissi, A., Iffly, J.F., Poirier, C., and Hoffmann, L. (2004), *Spatial Variability of Trends in the Rainfall-Runoff Relationship: A Mesoscale Study in the Mosel Basin* in Climatic Change, volume 66, Springer Netherlands, 67-87.

Figure 2-5 – Average annual air temperature, 7-year running mean and long-term annual mean 1961-1990 for the Findel-Airport station: 1947-2012



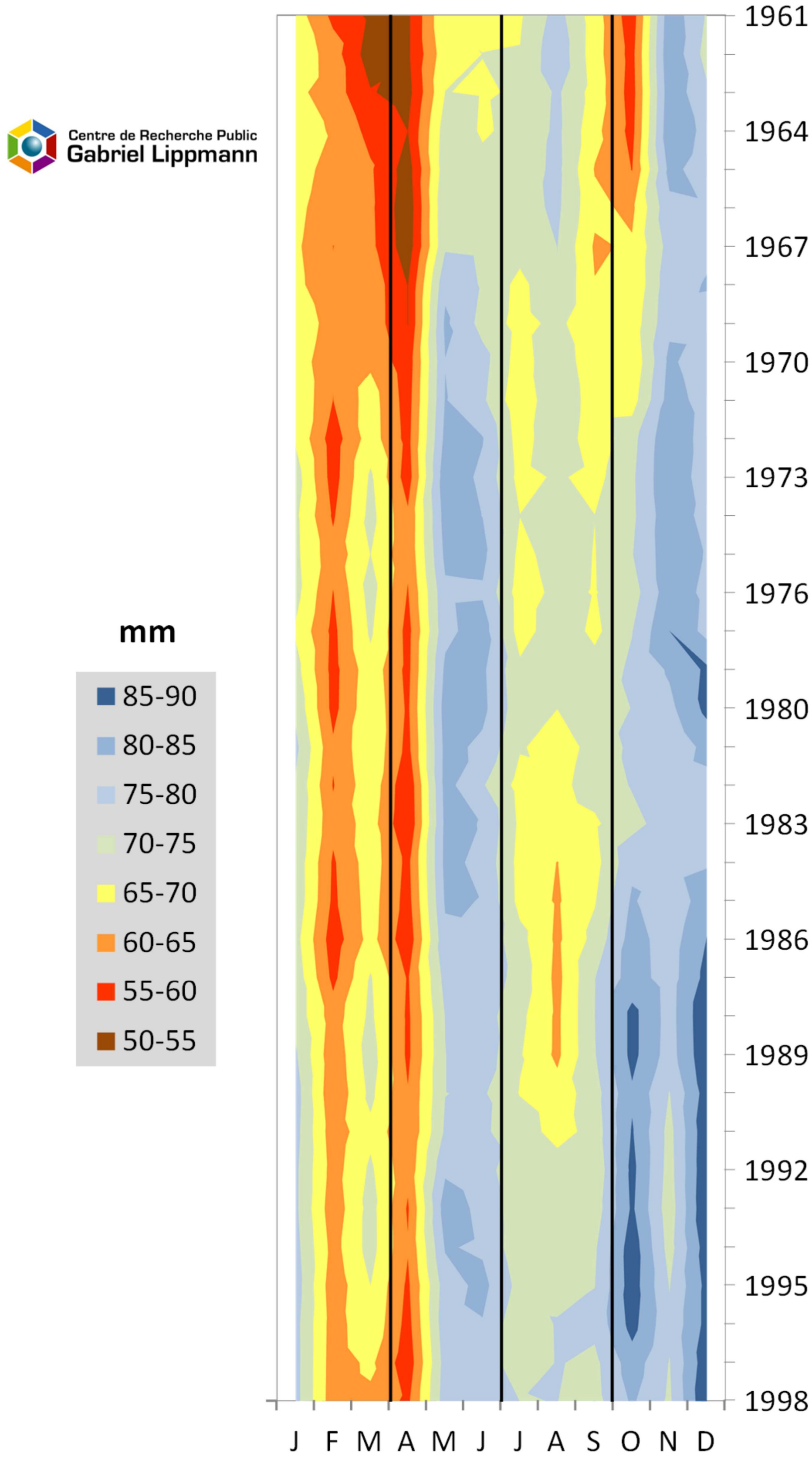
Source: Findel-Airport station (SMA) and *Luxembourg Institute of Science and TechnologyTechnology*, unpublished.

Figure 2-6 – Anomalies of annual air temperature from the reference period 1961-1990 for the Findel-Airport station: 1947-2012



Sources: Findel-Airport station (SMA) and *Luxembourg Institute of Science and Technology*, unpublished.
Note: Anomalies from the reference period 1961 till 1990: long-term mean: 8.3°C.

Figure 2-7 – Precipitation 30-year moving average: 1947-1998



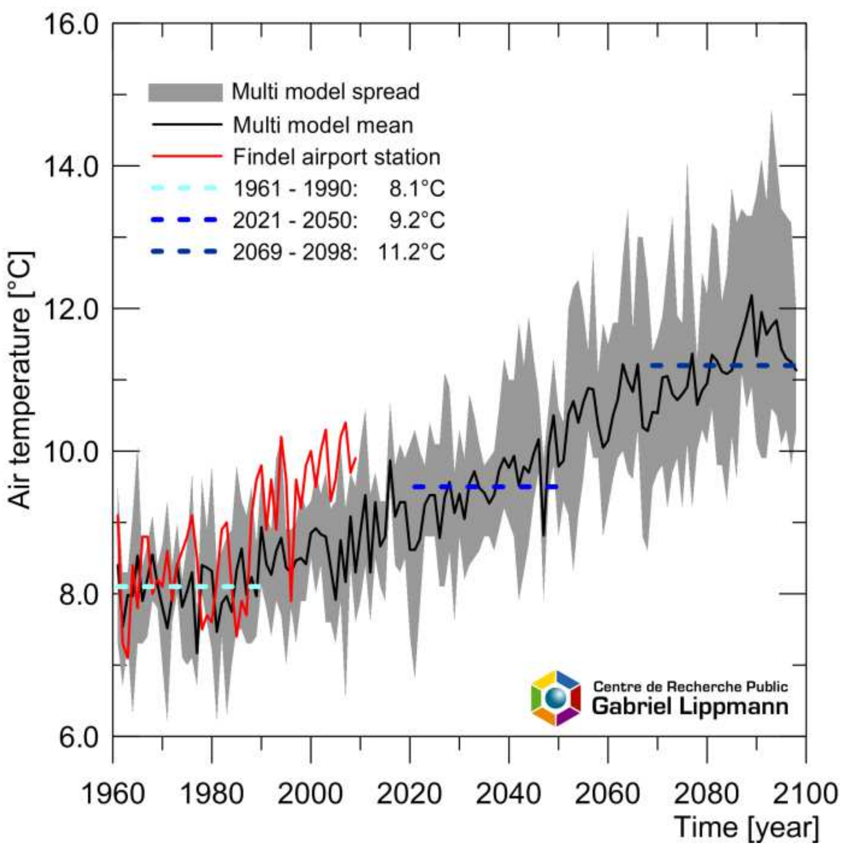
<u>Sources</u>: Findel-Airport station (SMA) and *Luxembourg Institute of Science and Technology*, unpublished.
<u>Note</u>: Values are given for middle of averaging period.

2.1.2.2 Climate projections: continuing rise in air temperature

Preliminarily results taken from a project from the Department "Environmental Research & Innovation" of the *Luxembourg Institute of Science and Technology* suggest an increase in mean air temperature for the Grand-Duchy of Luxembourg. Based on selected results of the FP6 ENSEMBLES project climate change projections,[37] mean annual temperatures are expected to reach up to 11.6°C for the period 2071 till 2100. This value refers to the GHG emission scenario A1B (Figure 2-8).

Preliminarily results concerning changes in precipitation suggest a relative stability in annual totals until 2100 (Figure 2-9). However, a substantial redistribution of seasonal precipitation totals can be expected in the second half of the 21st century, with a decrease in summer rainfall and an increase in winter precipitation (Figure 2-10).

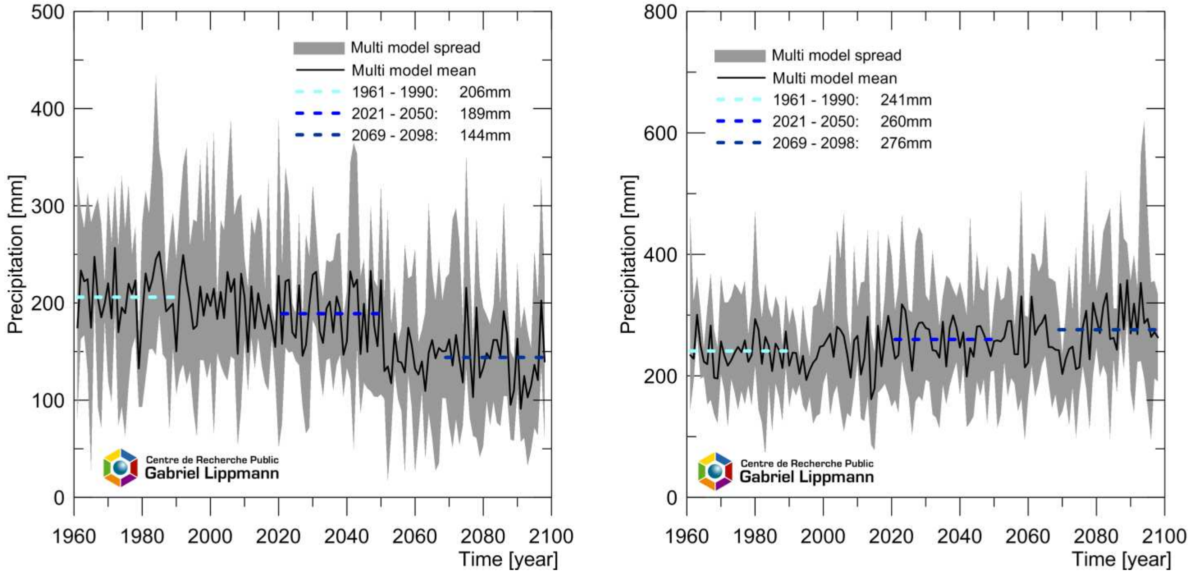
Figure 2-8 – Projections of mean annual air temperature



Source: *Luxembourg Institute of Science and Technology*, unpublished.
Notes: (1) based on selected ENSEMBLES data sets, A1B emission scenario.
(2) Anomalies from the reference period 1961 till 1970: long-term mean: 8.9°C.

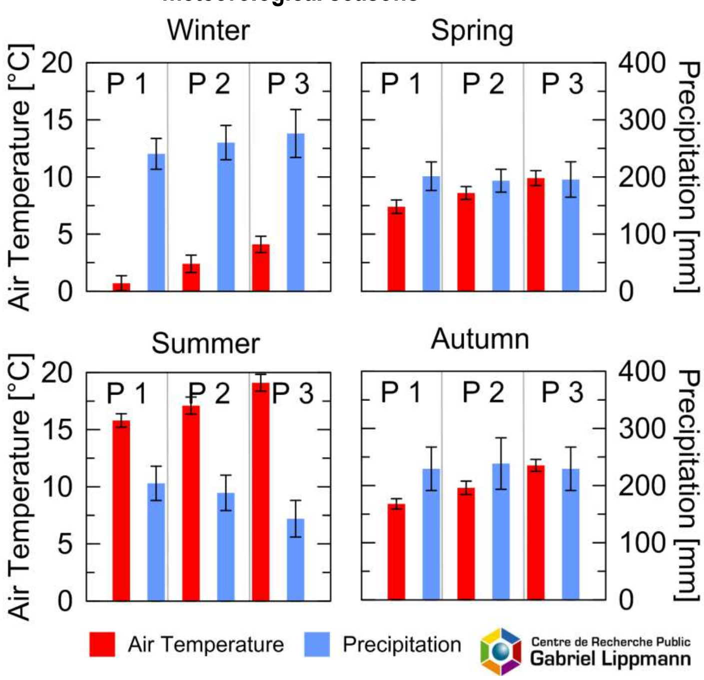
37 http://ensembles-eu.metoffice.com.

Figure 2-9 – Projections of precipitation sums for the meteorological seasons



Source: *Luxembourg Institute of Science and Technology*.
Notes: (1) based on selected ENSEMBLES data sets, A1B emission scenario.
(2) JJA = meteorological summer season (June – July – August); DJF = meteorological winter season (December – January – February).

Figure 2-10 – Projections of mean annual air temperature and precipitation sums for the meteorological seasons



Source: *Luxembourg Institute of Science and Technology*: Goergen, K., Beersma, J., Hoffmann, L., and Junk, J. (2013), *ENSEMBLES-based assessment of regional climate effects in Luxembourg and their impact on vegetation*, in Climatic Change, volume 119, Springer Netherlands, 761-773.

Notes: (1) based on selected ENSEMBLES data sets, A1B emission scenario.
(2) Periods: P1 = 1961-1990 // P2 = 2021-2050 // P3 = 2069-2098.

2.1.2.3 Expected impacts of climate change in Luxembourg: forests and water in the forefront

According to a report published in 2012 by the EEA,[38] reproducing an EEA map based on IPCC reports showing key past and projected impacts and effects for the main bio-geographic regions of Europe, Luxembourg is part of the "Central & Eastern Europe" area (cf. Map TS.1, p. 27 & Table TS.2, p. 28 of the aforementioned report). The threats identified for this peculiar region are:

- increase in warm temperature extremes;
- decrease in summer precipitation;
- increase in water temperature;
- increasing risk of forest fire;
- decrease in economic value of forests.

Two of these threats are of main concern for Luxembourg, **those relating to forests**. **Temperatures extremes** and **summer precipitation reduction** are also causes for concern due to their impacts on human health, especially of the most fragile persons and the elderly (heat, air quality), and impacts on water quality in summer when rivers flows are usually at their lowest.

According to the researchers of the *Luxembourg Institute of Science and Technology*, the projected changes in air temperature are likely to induce a modification of the vegetation period in Luxembourg. The start of the vegetation period is defined as the exceeding of the 5°C daily mean temperature threshold in spring for at least 30 successive days; the end of the vegetation period corresponds to the undershooting of this threshold until the end of the year.[39]

In Luxembourg, the **vegetation period** is expected to be initiated earlier in spring and to last longer into autumn (Figure 2-11). During the early stages of the vegetation period this might cause an increased risk of frost damages to vegetation.[40]

The increase of temperatures, especially during the winter period, already has significant impacts on the **phenology of plants** (earlier flowering dates) and animals (*e.g.* earlier breeding dates of birds, advancement of life cycle of insects, three instead of two yearly cycles), but also on the **migratory behaviour of birds and insects** (*i.e.* species that now hibernate in Luxembourg migrated in former times to Spain or Northern Africa). Furthermore, the temperature changes have an impact on the **bio-geography of plants and animals**, with new species with a Mediterranean distribution, formerly unknown in Luxembourg, which recently appeared in the country fauna

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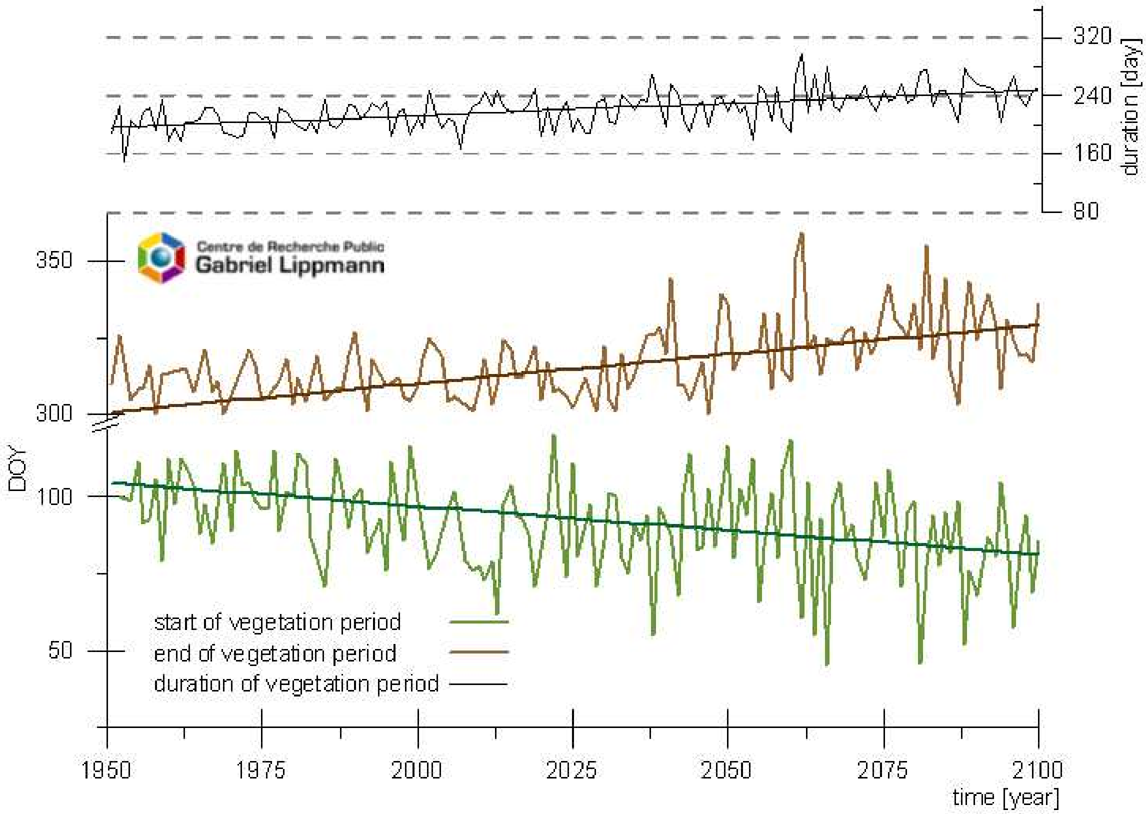
38 European Environment Agency, (2012), *Climate change, impacts and vulnerability in Europe 2012 – An indicator-based report*, EEA Report No 12/2012, Copenhagen (http://www.eea.europa.eu/publications/climate-impacts-and-vulnerability-2012).

39 Chmielewski, F.M., and Rötzer, T. (2001), *Response of tree phenology to climate change across Europe*. In Agricultural and Forest Meteorology, 108, 101-112.

40 Goergen, K., Beersma, J., Hoffmann, L., and Junk, J. (2013), *ENSEMBLES-based assessment of regional climate effects in Luxembourg and their impact on vegetation*, in Climatic Change, volume 119, Springer Netherlands, 761-773.

(*e.g. Nomophila noctuella*, *Udea ferrugalis*, *Brenthis daphne*) and flora (some moss species). Bio-climatic approaches also indicate that some relict species of the last glaciation period (*e.g. Lycaena helle*) will disappear from Luxembourg with the expected temperature increase.

Figure 2-11 - Start, end and duration of the vegetation period



Source: *Luxembourg Institute of Science and Technology*, unpublished.
Notes: (1) based on selected ENSEMBLES data sets, A1B emission scenario.
(2) End and duration of the vegetation period as defined by Chmielewski & Rötzer (2001).
(3) DOY = day(s) of year.

The climate projections for the second half of this century will also have significant impacts on the **bio-meteorological conditions** in Luxembourg. The higher air temperatures, especially stressful for humans during night in their recreation time, also increase the likelihood of extreme heat events such as the one that struck Europe in August 2003. Besides impact on the **human health**, this will also lead to more frequent and more stringent stress conditions for **agricultural plants and forestry**, most severely impacting perennial forest trees. Observations on the phytosanitary state of Luxembourg forest – a rather "old" forest – show a sharp degradation – which seems to have stabilised nowadays – resulting, among other factors, from climate change. The ageing of the forest also increases the risk of outbreak of diseases and of infestation by insects as well as other parasites that could proliferate if more mild winters and overall general temperatures are recorded in Luxembourg.

With regard to **water**, the most analysed phenomena so far are floods. It is known that; due to major redistributions of winter rainfalls, essentially, a higher inundation frequency is being recorded since the river systems have reacted to these changes with a statistically significant increase of maximum daily runoff during winter.[41] This is why an observation hydro-climatic network (*réseau d'observation hydro-climatologique*) has been put in place in the mid-1990s.[42] Its main functions consist in continuously (24/7) monitoring Luxembourg's water courses, and in the realization and the updating of an atlas of areas of the national territory subjected to swellings and floods. The network also suggests anti-flooding measures and participates to renaturation projects aiming at re-creating natural areas which have been used as natural reservoirs containing rising waters.[43]

2.1.3 Population and Workforce

2.1.3.1 A strong population growth driven by immigration

At the end of 2015, the **population of Luxembourg** amounted to 562 958 inhabitants. Within slightly more than 50 years, the residential population has grown by some 248 100 inhabitants or about 78.8% – 48.4% since 1990 (Table 2-4). The average annual growth rate of the resident population of Luxembourg is elevated compared to the rates of its neighbouring regions: between 1990 and 2015, the average annual growth rate for Luxembourg (1.5%) was about 4 times lower than its equivalent for the *Grande Région*.[44] It even reached 1.7% p. a. since 2000 (Figure 2-13).

Demographic growth in Luxembourg is actually dominated by **immigration**. Nationals themselves saw their number stagnating, and without immigrants taking the citizenship of Luxembourg they would even have fallen. At the end of 2015, 46.0% of the residential population did not have the citizenship of Luxembourg. This percentage was only around 30% in 1990, as depicted in Figure 2-12. The main driver behind these demographic trends is the economic restructuring and development of the country towards the tertiary sector coupled with attractive wages, which is presented in Section 2.1.4.

Since population projections are based on scenarios derived from past statistical data, population forecasts a continuation of the demographic trend in Luxembourg. Projections calculated by STATEC in 2010 forecast, under the "baseline" scenario, that almost 750 000 inhabitants could be

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41 Pfister, L., Drogue, G., Poirier, C., and Hoffmann, L. (2005), *Evolution du climat et répercussions sur le fonctionnement des hydrosystèmes au Grand-Duché de Luxembourg au cours des 150 dernières années* in Ferrantia 43, Musée National d'Histoire Naturelle, Luxembourg, 85-100. (http://ps.mnhn.lu/ferrantia/publications/Ferrantia43.pdf)

42 http://www.hydroclimato.lu.

43 For an example, look at http://www.luxnatur.lu/alzrena1.htm.

44 Refer to Box 2-1 for a presentation of the *Grande Région*.

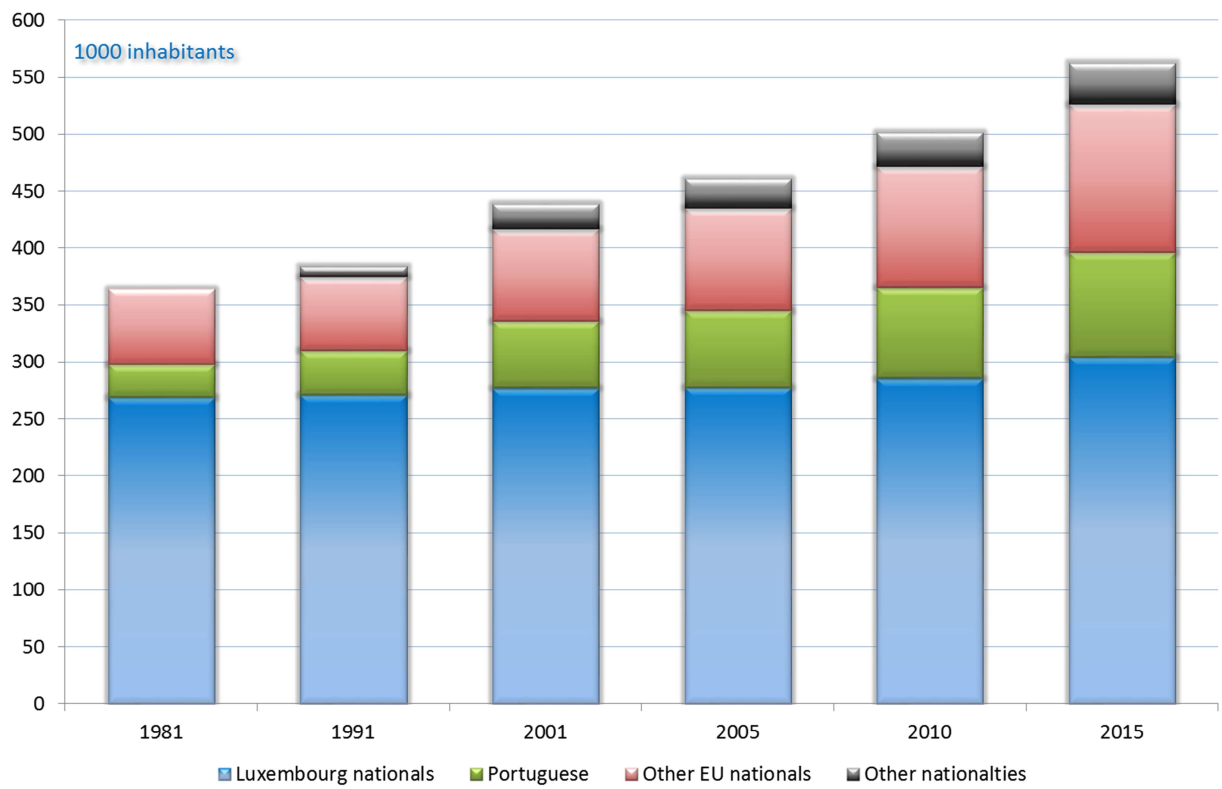
living in Luxembourg by 2050 (Figure 2-13).[45] As it is the case for any forecasts, these predictions should be treated with caution because they cannot predict radical changes in the economic structure or demographics of a country, especially a small one whose economy relies heavily on a few economic sectors. However, since population growth is one of the key drivers for domestic energy use, mainly in the housing and transportation sector, these forecasts illustrate the scale of one of the many challenges Luxembourg is facing in the definition of measures aiming at reducing its GHG emissions.

Table 2-4 – Population: 1960-2015

calculated on 31st December	1960	1990	1995	2000	2005	2010	2015
Resident population (x 1000)	314.9	379.3	405.7	433.6	469.1	502.1	563.0

Source: STATEC, Statistical Yearbook, Table B.1100 (updated 31 March 2017): http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=12856&IF_Language=fra&MainTheme=2&FldrName=1

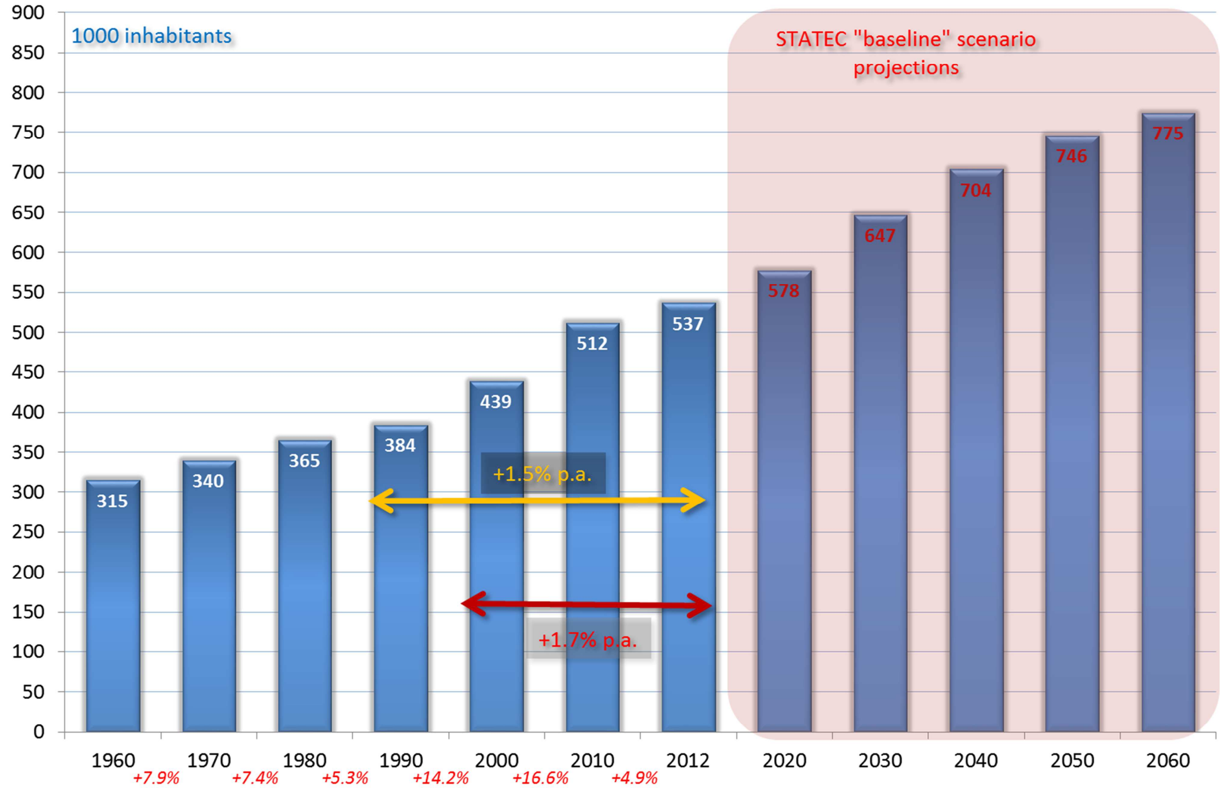
Figure 2-12 – Population structure on 31st December: 1981-2015



Source: STATEC, *Statistical Yearbook*, Table B.1101 (updated 31 March 2017): http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=12853&IF_Language=fra&MainTheme=2&FldrName=1
Note: 1981, 1991 and 2001 data are coming from population censuses held every decade, other years are calculated by STATEC.

45 For details, see STATEC (2012), *Projections socio-économiques 2010-2060*, Bulletin du STATEC N° 5/2010, Luxembourg, pages 262-272 (http://www.statistiques.public.lu/fr/publications/series/bulletin-statec/2010/05-10-Projpop/index.html). Other projections, which are a bit lower than STATEC's baseline scenario, are also produced in the framework of the European Commission Ageing Working Group: http://europa.eu/epc/working_groups/ageing_en.htm and http://europa.eu/epc/pdf/2012_ageing_report_en.pdf, as well as http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Population_projections.

Figure 2-13 – Population growth on 31st December: 1960-2060



Sources: STATEC, Statistical Yearbook, Table B.1100 (updated 31 March 2017):
http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=12856&IF_Language=fra&MainTheme=2&FldrName=1
STATEC, Bulletin du STATEC N°5/2010 – Projections socio-économiques 2010-2060 (published 26 October 2010):
http://www.statistiques.public.lu/fr/publications/series/bulletin-statec/2010/05-10-Projpop/index.html

Box 2-1 – The *Grande Région*

The *Grande Région* is the geographic unit that includes Luxembourg, the region of Wallonia in Belgium, Lorraine in France and two German *Länder*: Saarland and Rheinland-Pfalz.

Today, this structure is more a cooperative space than an effective integrated region defining and modelling its own policies and development. This is the result of the diversity of the territories constituting the *Grande Région*, of its dimension and of the barriers created by institutional and administrative structures in each country. De facto, being a sovereign state amongst country regions, Luxembourg has a special status in this cooperative space: it is the main driving force behind the *Grande Région*, a position re-enforced by its demographic and economic development as shown by the figures in the table below.

Grande Région entity	population change (1st January) % 1990-2015	population annual average growth rate (1st January) % 1990-2015	GDP at current price annual average growth rate % 1990-2015	total employment in 2014 1990=100
BE-Wallonia	10.67%	0.41%	3.57%	116
DE-Rheinland-Pfalz	8.37%	0.32%	2.35%	117
DE-Saarland	-7.12%	-0.29%	2.48%	116
FR-Lorraine	1.51%	0.06%	2.06%	102
Luxembourg	**48.42%**	**1.59%**	**7.23%**	**201**

More information on the *Grande Région* can be found on line:
http://www.granderegion.net/fr/index.html
http://www.grande-region.lu/eportal/pages/HomeTemplate.aspx

2.1.3.2 Workforce: the importance of cross-border commuters

The economic restructuring and development of Luxembourg led to a doubling of the workforce in the last 20 years. The resident population of Luxembourg nationality was unable to meet this increasing demand for labour. The number of Luxembourg nationals employed increased from some 103 700 units in 1995 to 146 683 in 2015, representing an average annual growth rate of only 2.5%. How, therefore, could this urgent economic need be satisfied? The initial response was to resort to **immigration**. The number of foreign employees living and working in Luxembourg rose from 54 900 in 1995 to 88 620 in 2015 – an average annual growth rate of 2.1%. But, this was not enough. So the **cross-border commuters** came into play. Between 1995 and 2015, the number of cross-border workers increased from 56 900 to 171 100, at an average annual growth rate of 6% (Table 2-5).[46]

For 2015, among the persons employed, 50.2% of the commuters came from France, 24.9% from Germany and 24.9% from Belgium. In total, the commuters accounted for 42% of the total workforce in Luxembourg and for 30% (*i.e.* more than a quarter) of the residential population (Figure 2-14).[47] The commuting flows amongst the various regions of the *Grande Région* clearly show the economic attraction of Luxembourg (Figure 2-15).

A vast majority of workers from abroad commute by car.[48] However, in order to alter the current modal split of home-work journeys, Luxembourg invests predominantly and jointly with the neighbouring regions into the public transport offer.

Table 2-5 – Persons employed: 1995-2015

in thousand persons	1995	2000	2005	2010	2015
Resident workers – Lux. nationals *(B.3106 & E.2309)*	103.70	106.50	108.50	117.80	146.68
Resident workers – foreigners *(B.3106 & B.3005)*	54.90	67.20	77.90	89.70	88.62
Cross-border workers *(B.3005)*	56.90	90.30	121.20	151.90	171.10
Total workers/employment *(E.2309)*	215.50	264.00	307.60	359.40	406.40

Sources: Environment Agency calculations on the basis of STATEC, Statistical Yearbook, Table B.3106 (updated 28 October 2013), B.3107 (updated 31 March 2017) & E.2309 (updated 31 March 2017):
http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=12919&IF_Language=fra&MainTheme=2&FldrName=3&RFPath=92
http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=13161&IF_Language=fra&MainTheme=5&FldrName=2&RFPath=21

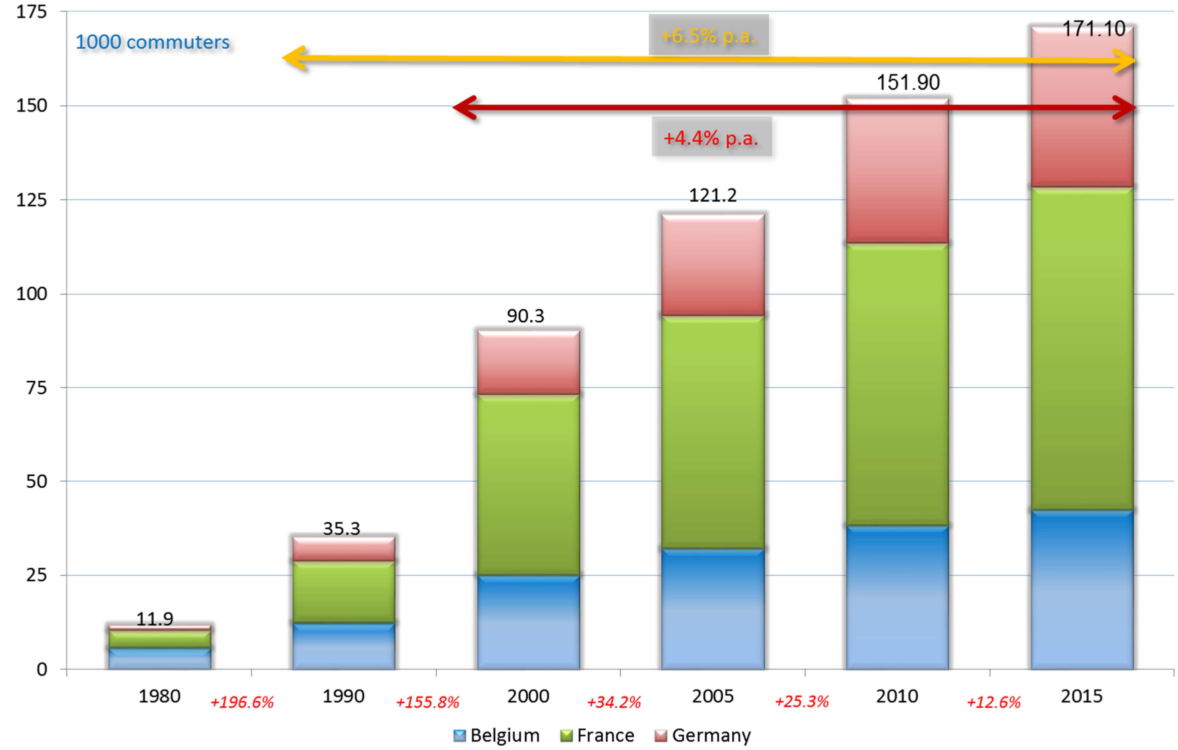
Notes: (1) due to revisions in the calculation of the various measures of employment, it is not possible to go back further than 1995.
(2) This table presents the total employment, *i.e.* paid workers and self-employed workers. Figures are annual cumulative averages.

46 Figures indicated in this paragraph are annual cumulative averages.

47 Calculated from STATEC, Statistical Yearbook, Table B.3107: http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=12919&IF_Language=fra&MainTheme=2&FldrName=3&RFPath=92

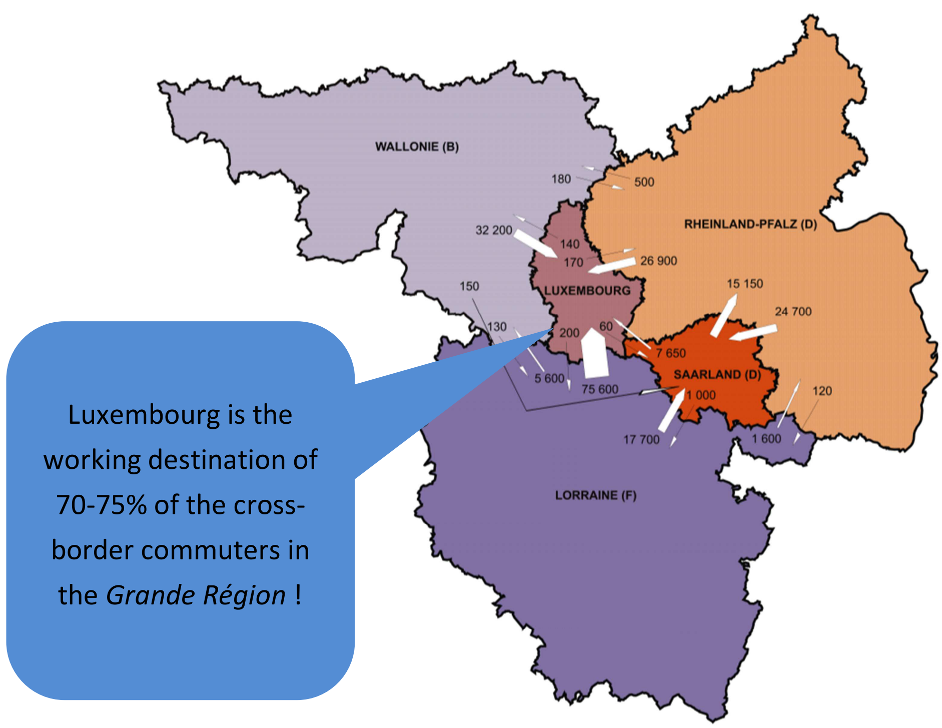
48 According to a recent study, for 2010, it was estimated that 86% of the cross-border commuters were only using their car for their home-work journeys. This percentage was 91% in 2007: http://www.ceps.lu/?type=module&id=104&tmp=1900.

Figure 2-14 – Cross-border commuters' growth: annual cumulative averages 1980-2015



Source: STATEC, Statistical Yearbook, Table B.3005 (updated 31 March 2017): http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=12919&IF_Language=fra&MainTheme=2&FldrName=3&RFPath=92

Figure 2-15 – COMMUTING FLOWS 2011



Source: INSEE, IGSS, STATEC, IWEPS, Statistisches Amt Saarland, Statistisches Landesamt Rheinland-Pfalz: http://www.statistiques.public.lu/stat/TableViewer/document.aspx?ReportId=498&IF_Language=fra&MainTheme=2&FldrName=3&RFPath=92.

2.1.4 Economic profile

One of the main characteristics of economic growth in Luxembourg is its volatility. Generally speaking, the economic cycle in Luxembourg follows that of other European countries, but the amplitude of the GDP variations is more pronounced. This is a common feature of small economies, open to the outside world, and therefore more vulnerable to external shocks. It would however appear that over the past ten years the amplitude of GDP variations in Luxembourg has diminished, as has the gap in relation to the European cycle.

The economic restructuring and development of the country towards the tertiary sector from the 1960s-70s, led to the following economic cycles since 1990:

- up to 1992, the continuation of the exceptional growth initiated around 1985;
- the effects of the economic slowdown in Luxembourg during the period between 1992 and 1996 and the economic downturn in 2001 – as well as the less impressive growth in 2002-2004 – which is mirrored by a stagnation of the GDP level per inhabitant in Luxembourg in comparison with the EU-15;
- the good economic performance of Luxembourg between 2005 and 2008;
- the financial and economic crisis that started at the end of 2008 and that has been particularly pronounced in the first semester of 2009;
- from 2010 onwards, a very slow recovery could be observed, though it flattened quickly for the industry and commercial sectors.

Nowadays, **gross value added** is mainly generated in the financial intermediation (banking and insurances), real estate and services to business sector. The share of total gross value added in this branch has increased from about 38% in 1995 to 46% in 2015.[49] While the commercial sector has maintained a constant share at about 18 to 17%, the share of the industry sector has decreased significantly from 15% in 1995 to 7.0% in 2015. Other service activities ranged between a share of 20 to 25% and construction kept a rather constant share in total gross value added between 5 and 6%. The contribution of the agricultural sector is negligible with less than 1% (Table 2-6 & Figure 2-16).

Nevertheless, GHG emissions trends in Luxembourg are not so much influenced by the economic profile of the country, but for the most part by:

- the energy-mix for both production and consumption of fuels (liquid, solid, gaseous, biomass): more on this in the next section;

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49 Data prior to 1995 are and will not be translated into the new European System of Accounts (ESA).

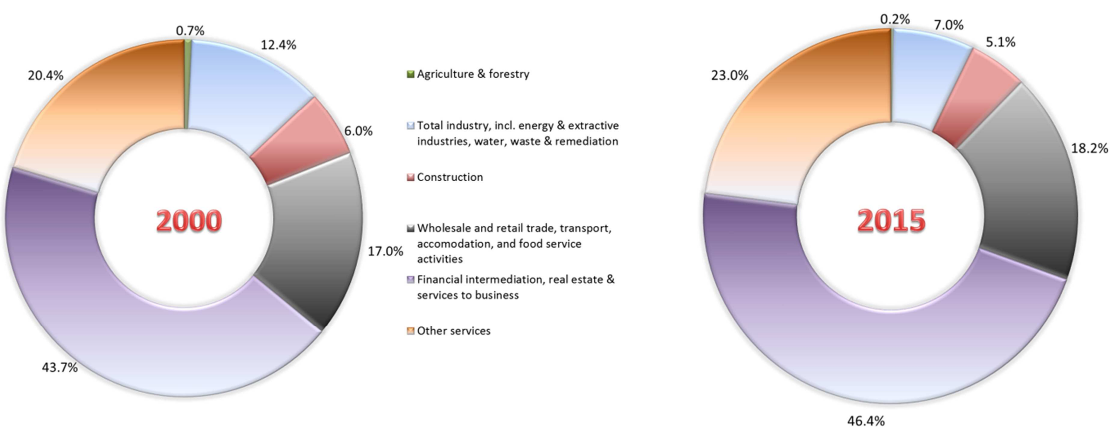
- due to its size and the size of its energy and industrial sector, structural changes in these sectors that could be initiated by a single entity;
- road transportation related fuel sales: more on this in Section 2.1.6.

Table 2-6 – Sectoral gross value added at current prices: 1995-2015

mio. EUR		2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Agriculture, forestry & fishing (A)		143.6	106.8	114.3	152.3	118.9	93.0	99.3	108.9	158.5	123.1	127.7	112.9
	%	0.7%	0.4%	0.4%	0.5%	0.4%	0.3%	0.3%	0.3%	0.4%	0.3%	0.3%	0.2%
Total industry, including extractive industries, energy production & distribution, water supply, sewerage, waste		2575.2	2877.2	2947.3	3582.7	3245.0	2299.3	2635.0	2695.1	2662.7	2909.8	3196.3	3243.5
management and remediation activities (B to E)	%	12.4%	10.8%	9.8%	10.8%	9.6%	7.1%	7.3%	7.0%	6.8%	7.0%	7.3%	7.0%
Construction (F)		1242.3	1531.4	1670.3	1925.6	1937.0	1911.8	1926.8	2120.5	2034.1	2129.0	2446.9	2340.4
	%	6.0%	5.8%	5.6%	5.8%	5.7%	5.9%	5.4%	5.5%	5.2%	5.1%	5.6%	5.1%
Wholesale and retail trade, transport, accomodation		3530.5	4227.0	4713.9	4830.5	5793.9	5213.9	6045.4	7286.4	7030.3	7688.7	7914.4	8411.9
and food service activities (G to I)	%	17.0%	15.9%	15.7%	14.6%	17.1%	16.0%	16.8%	19.0%	17.9%	18.6%	18.1%	18.2%
Financial and insurance activities; real estate activities; professional, scientific and technical activities;		9092.7	11765.9	14177.6	15558.2	15410.3	15327.6	16739.4	17415.3	17817.1	18707.1	20082.1	21470.8
administrative and support service activities (K to N)	%	43.7%	44.4%	47.1%	47.1%	45.5%	47.0%	46.6%	45.3%	45.5%	45.2%	45.8%	46.4%
Other services: information and communication; public administration, defence, education, human health and social work activities; arts, entertainment and recreation;		4243.8	6010.5	6470.7	6985.6	7383.9	7755.7	8470.5	8806.1	9478.1	9826.2	10076.8	10650.5
Oher service activities; activities of household (J & O to U)	%	20.4%	22.7%	21.5%	21.1%	21.8%	23.8%	23.6%	22.9%	24.2%	23.7%	23.0%	23.0%
Total: all NACE rev2 branches		**20828.1**	**26518.7**	**30094.2**	**33034.9**	**33889.1**	**32601.5**	**35916.5**	**38432.6**	**39180.8**	**41383.8**	**43844.1**	**46230.2**
Annual growth rate - current prices				**13.5%**	**9.8%**	**2.6%**	**-3.8%**	**10.2%**	**7.0%**	**1.9%**	**5.6%**	**5.9%**	**5.4%**
Annual growth rate - constant prices/in volume				**5.6%**	**8.5%**	**-1.1%**	**-5.7%**	**5.6%**	**1.4%**	**-0.4%**	**4.3%**	**4.3%**	**4.1%**

Source: STATEC, *Statistical Yearbook*, Tables E.2304 (current prices) & E.2305 (constant prices) (updated 24 February 2016): http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=13158&IF_Language=fra&MainTheme=5&FldrName=2&RFPath=21

Figure 2-16 – Sectoral gross value added at current prices: 2000 & 2015



Source: STATEC, *Statistical Yearbook*, Table E.2304 (updated 31 March 2017): http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=13157&IF_Language=fra&MainTheme=5&FldrName=2&RFPath=21

2.1.5 Energy

2.1.5.1 A total change in Luxembourg's energy-mix

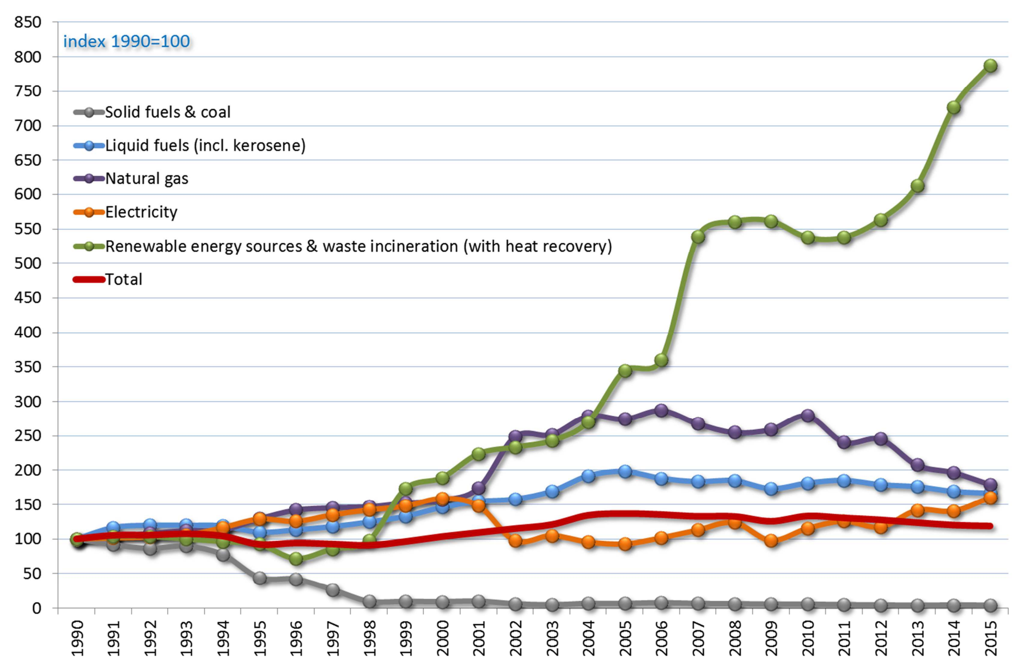
Primary and final energy consumption in Luxembourg experienced dramatic changes since 1990. Overall **primary energy consumption** increased by 18.5% between 1990 and 2015. Whereas solid fuels and coal declined by more than 96% over the period, liquid fuels (incl. kerosene) and natural gas consumptions increased by 167% and 180% respectively (Table 2-7 & Figure 2-17).

Table 2-7 – Primary energy consumption: 1990-2015

TJ	1990 (base year)	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Solid fuels & coal	49939.83	45812.91	43145.01	44770.76	38726.29	22010.21	20893.02	13306.17	4861.42	4814.73	4594.52	4957.84	3083.62
	33.23%	*28.98%*	*27.20%*	*27.75%*	*24.76%*	*15.90%*	*14.78%*	*9.57%*	*3.57%*	*3.33%*	*2.96%*	*3.02%*	*1.79%*
Liquid fuels (incl. kerosene)	66030.62	76910.67	79078.34	78994.97	78578.11	72455.60	74715.90	77882.37	82209.79	87715.26	96236.54	102063.69	104261.62
	43.94%	*48.66%*	*49.86%*	*48.97%*	*50.24%*	*52.35%*	*52.85%*	*56.00%*	*60.30%*	*60.72%*	*61.99%*	*62.27%*	*60.42%*
Natural gas (1)	19925.91	20717.94	21593.35	22427.07	22593.81	25819.65	28324.39	29023.46	29305.68	30397.85	31231.01	34718.00	49629.00
	13.26%	*13.11%*	*13.61%*	*13.90%*	*14.45%*	*18.65%*	*20.03%*	*20.87%*	*21.50%*	*21.04%*	*20.12%*	*21.18%*	*28.76%*
Electricity	13256.15	13464.58	13631.32	14006.50	15423.82	17083.75	16644.80	17889.96	18859.16	19580.75	21059.69	19649.82	12952.77
	8.82%	*8.52%*	*8.59%*	*8.68%*	*9.86%*	*12.34%*	*11.77%*	*12.86%*	*13.83%*	*13.55%*	*13.56%*	*11.99%*	*7.51%*
Heat	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.03	2.02	6.47
	NA	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*0.00%*	*0.00%*	*0.00%*
Renewable energy sources & w	1125.52	1167.21	1167.21	1125.52	1083.84	1042.15	808.71	964.61	1100.93	1946.32	2128.82	2520.68	2630.06
Incineration (with heat recovery	*0.75%*	*0.74%*	*0.74%*	*0.70%*	*0.69%*	*0.75%*	*0.57%*	*0.69%*	*0.81%*	*1.35%*	*1.37%*	*1.54%*	*1.52%*
Total	**150278.03**	**158073.31**	**158615.23**	**161324.82**	**156405.87**	**138411.36**	**141386.82**	**139066.58**	**136336.98**	**144454.91**	**155250.60**	**163912.04**	**172563.53**

TJ	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Solid fuels & coal	2369.15	3328.54	3248.87	3876.79	3280.32	3136.57	2801.27	2806.63	2443.45	2249.59	2005.86	2234.78	2052.95
	1.31%	*1.65%*	*1.58%*	*1.91%*	*1.65%*	*1.58%*	*1.49%*	*1.41%*	*1.25%*	*1.17%*	*1.08%*	*1.24%*	*1.15%*
Liquid fuels (incl. kerosene)	111789.85	126709.57	130884.49	124308.27	121227.03	122120.30	114419.02	119823.60	122367.06	118245.32	116275.75	111686.26	109986.68
	61.74%	*62.91%*	*63.82%*	*61.24%*	*60.92%*	*61.40%*	*60.75%*	*59.99%*	*62.53%*	*61.76%*	*62.65%*	*61.98%*	*61.75%*
Natural gas (1)	50238.00	55632.00	54720.18	57237.24	53426.14	50856.70	51751.75	55665.22	48021.10	48894.89	41398.28	39223.62	35770.96
	27.74%	*27.62%*	*26.68%*	*28.20%*	*26.85%*	*25.57%*	*27.48%*	*27.87%*	*24.54%*	*25.54%*	*22.31%*	*21.77%*	*20.08%*
Electricity	13931.02	12698.58	12323.47	13490.64	14981.85	16412.67	12987.43	15290.40	16677.00	15567.70	18791.88	18634.29	21238.39
	7.69%	*6.30%*	*6.01%*	*6.65%*	*7.53%*	*8.25%*	*6.90%*	*7.66%*	*8.52%*	*8.13%*	*10.13%*	*10.34%*	*11.92%*
Heat	9.85	13.60	17.53	21.62	28.95	41.54	62.85	87.53	122.76	165.96	220.21	247.12	205.62
	0.01%	*0.01%*	*0.01%*	*0.01%*	*0.01%*	*0.02%*	*0.03%*	*0.04%*	*0.06%*	*0.09%*	*0.12%*	*0.14%*	*0.12%*
Renewable energy sources & w	2736.22	3041.45	3883.23	4049.26	6063.63	6310.98	6320.76	6052.85	6054.97	6343.76	6893.28	8175.12	8868.42
Incineration (with heat recovery	*1.51%*	*1.51%*	*1.89%*	*1.99%*	*3.05%*	*3.17%*	*3.36%*	*3.03%*	*3.09%*	*3.31%*	*3.71%*	*4.54%*	*4.98%*
Total	**181074.09**	**201423.74**	**205077.78**	**202983.83**	**199007.92**	**198878.76**	**188343.07**	**199726.22**	**195686.34**	**191467.22**	**185585.25**	**180201.19**	**178123.02**

Figure 2-17 –Primary energy consumption: 1990-2015



Source: STATEC, *Statistical Yearbook*, Table A.4200 (updated 31 March 2017): http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=12759&IF_Language=fra&MainTheme=1&FldrName=4&RFPath=54

Notes: (1) Natural gas is expressed in GCV;
(2) Only the organic fraction of waste is counted. The biogas included as renewable energy source is expressed in GCV that also comprises blended biofuels. There is a break in the time-series between 1999 & 2000 (||).

Final energy consumption increased by 18% between 1990 and 2015. As for primary energy consumption, all the energy sources have seen their consumption increase over the period, except solid fuels and coal (Table 2-8 & Figure 2-18).

However, over the period 1990-2015, the final energy-mix of Luxembourg changed considerably with a dropping share for solid fuels – for which the main part was used in the iron and steel industry – in favour of liquid fuels and natural gas and, to a lesser extent, to new energy sources based on biomass. Indeed, in 2015, 81.7% of the **final energy consumption** was covered by fossil fuels – 64.1% by liquid fuels including the important volume of road fuels as well as kerosene,[50] 15.6% by natural gas and 1.2% by coal. The remaining 18.3% of the consumption were either electricity (13.19%) and heat (1.37%) or renewable energy sources, including organic waste incineration with energy recovery, biogas, and biofuels (3.7%). Going back to 1990, 23.8% of the final energy consumption was stemming from solid fuels and coal, 46% from liquid fuels, 13.5% from natural gas and 10.4% from electricity (Table 2-8 & Figure 2-18). What did happen?

- Regarding **solid fuels and coal**, the important decline (-94.0%) is the result of a change in production processes in the steel industry sector: the production process was moved from blast furnaces to electric arc furnaces between 1994 and 1998 and, therefore, solid fuels (mainly imported coke, but also imported anthracite) were replaced, to a very large extent, by electricity and natural gas;
- **Liquid fuels** increase (+164.4%) was driven by road fuel sales and kerosene, but with the former being 4 to 5 times higher in quantity than the latter. This is especially "road fuel sales to non-residents" that explains a great deal of the sharp increase (see Section 2.1.6);
- The 143% increase in **natural gas** final consumption followed the continuous extension of the natural gas network in Luxembourg so that this fuel ranked second after the consumption of liquid fuels in 2015 – and even first if "road fuel sales to non-residents" and kerosene are not considered.

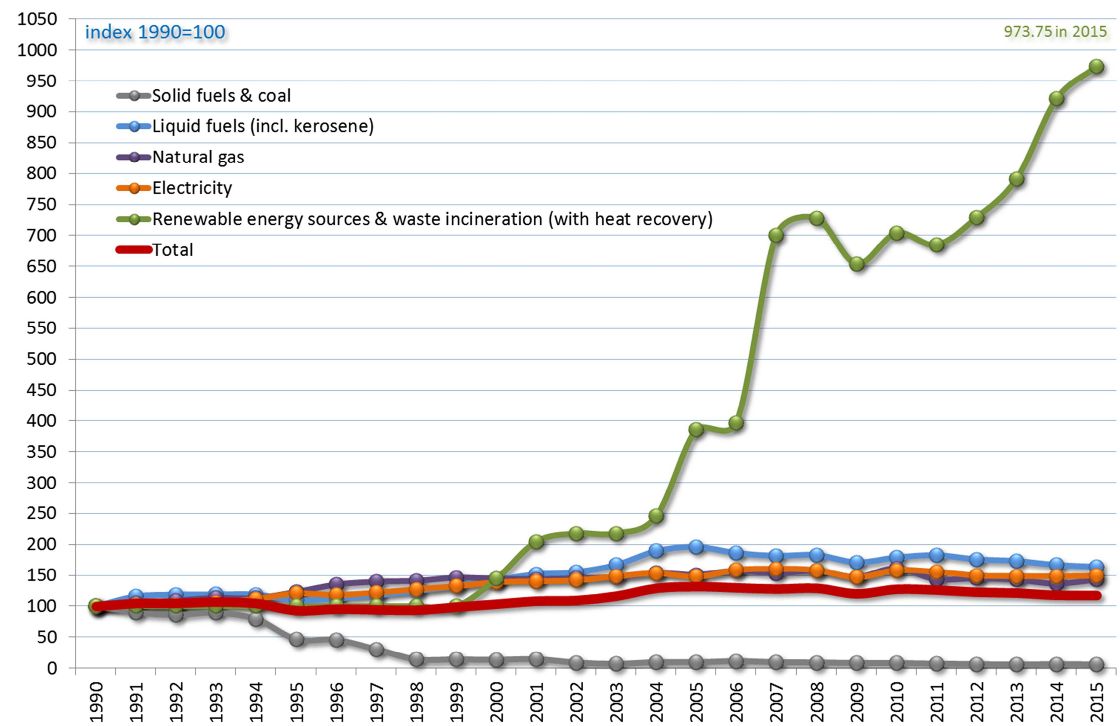
50 Diesel being the first liquid fuel in terms of volumes sold. The liquid fuel consumption in Luxembourg is much lower than the level of fuel sales, because large amounts of road fuels are bought by foreign commuters and transit traffic passing through Luxembourg: see section 2.1.6 below.

Table 2-8 – Final energy consumption: 1990-2015

TJ	1990 (base year)	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Solid fuels & coal	34331.76	30814.85	29475.07	30689.24	27268.21	16035.03	15670.77	10422.20	4882.65	4835.75	4594.52	4957.84	3083.62
	23.83%	*20.38%*	*19.46%*	*19.85%*	*18.05%*	*11.91%*	*11.35%*	*7.64%*	*3.60%*	*3.39%*	*3.07%*	*3.16%*	*1.95%*
Liquid fuels (incl. kerosene)	66193.31	76911.52	78669.97	78837.44	78753.71	72682.85	74734.38	78046.98	82554.07	88082.74	94644.90	100723.34	103120.21
	45.95%	*50.87%*	*51.93%*	*51.00%*	*52.14%*	*53.99%*	*54.13%*	*57.20%*	*60.90%*	*61.67%*	*63.27%*	*64.30%*	*65.18%*
Natural gas (1)	19426.75	20389.72	21227.08	22064.44	21989.91	23906.63	26251.24	27155.58	27436.94	28435.91	28125.74	27997.84	28258.28
	13.49%	*13.49%*	*14.01%*	*14.27%*	*14.56%*	*17.76%*	*19.01%*	*19.90%*	*20.24%*	*19.91%*	*18.80%*	*17.87%*	*17.86%*
Blast furnaces gas	8 457.34	7 234.79	6 196.46	6 514.24	5 503.55	2 731.89	2 511.66	1 347.31	NO	NO	NO	NO	NO
	5.87%	*4.79%*	*4.09%*	*4.21%*	*3.64%*	*2.03%*	*1.82%*	*0.99%*	*NA*	*NA*	*NA*	*NA*	*NA*
Electricity	14988.74	15198.08	15281.82	15826.10	16747.20	18045.11	17710.16	18254.45	19091.81	19835.80	20790.21	21033.19	21260.54
	10.41%	*10.05%*	*10.09%*	*10.24%*	*11.09%*	*13.40%*	*12.83%*	*13.38%*	*14.08%*	*13.89%*	*13.90%*	*13.43%*	*13.44%*
Heat (2)	NO	NO	NO	NO	125.60	586.15	547.21	563.54	949.98	986.41	503.93	624.35	1086.98
	NA	*NA*	*NA*	*NA*	*0.08%*	*0.44%*	*0.40%*	*0.41%*	*0.70%*	*0.69%*	*0.34%*	*0.40%*	*0.69%*
Renewable energy sources & waste Incineration (with heat recovery) (3)	644.77	644.77	644.77	644.77	644.77	644.77	644.77	644.77	644.77	644.77	929.70	1321.31	1405.98
	0.45%	*0.43%*	*0.43%*	*0.42%*	*0.43%*	*0.48%*	*0.47%*	*0.47%*	*0.48%*	*0.45%*	*0.62%*	*0.84%*	*0.89%*
Total	**144042.67**	**151193.72**	**151495.17**	**154576.24**	**151032.95**	**134632.42**	**138070.20**	**136434.83**	**135560.21**	**142821.38**	**149589.00**	**156657.87**	158215.602

TJ	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Solid fuels & coal	2369.15	3328.54	3248.87	3876.79	3280.32	3136.57	2801.27	2806.63	2443.45	2249.59	2005.86	2234.78	2052.95
	1.41%	*1.78%*	*1.71%*	*2.07%*	*1.77%*	*1.68%*	*1.61%*	*1.52%*	*1.34%*	*1.27%*	*1.14%*	*1.31%*	*1.21%*
Liquid fuels (incl. kerosene)	110821.65	125715.23	130171.42	123605.43	120541.81	121487.76	113538.02	118810.49	121233.69	116795.59	114952.35	110728.16	108814.71
	65.83%	*67.37%*	*68.35%*	*65.86%*	*65.21%*	*65.10%*	*65.36%*	*64.45%*	*66.45%*	*65.80%*	*65.54%*	*65.06%*	*64.12%*
Natural gas (1)	28673.98	29942.32	29338.04	30622.60	29822.71	30616.00	28658.82	31411.99	27916.40	28262.17	27789.82	26536.40	27835.84
	17.03%	*16.04%*	*15.40%*	*16.32%*	*16.13%*	*16.41%*	*16.50%*	*17.04%*	*15.30%*	*15.92%*	*15.84%*	*15.59%*	*16.40%*
Blast furnaces gas	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	NA	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Electricity	22252.42	23007.38	22149.43	23806.48	24097.50	23750.44	22004.89	23734.71	23343.11	22449.55	22315.52	22256.43	22390.44
	13.22%	*12.33%*	*11.63%*	*12.68%*	*13.04%*	*12.73%*	*12.67%*	*12.88%*	*12.79%*	*12.65%*	*12.72%*	*13.08%*	*13.19%*
Heat (2)	2818.44	3036.13	3055.77	3210.55	2581.94	2922.39	2483.81	3036.59	3102.44	3045.38	3230.12	2511.90	2330.57
	1.67%	*1.63%*	*1.60%*	*1.71%*	*1.40%*	*1.57%*	*1.43%*	*1.65%*	*1.70%*	*1.72%*	*1.84%*	*1.48%*	*1.37%*
Renewable energy sources & waste Incineration (with heat recovery) (3)	1406.76	1586.77	2489.86	2562.50	4518.54	4697.03	4219.33	4539.12	4414.70	4700.15	5103.19	5938.32	6278.42
	0.84%	*0.85%*	*1.31%*	*1.37%*	*2.44%*	*2.52%*	*2.43%*	*2.46%*	*2.42%*	*2.65%*	*2.91%*	*3.49%*	*3.70%*
Total	**168342.40**	**186616.37**	**190453.38**	**187684.35**	**184842.82**	**186610.19**	**173706.13**	**184339.52**	**182453.78**	**177502.42**	**175396.86**	**170205.98**	169702.932

Figure 2-18 – Final energy consumption: 1990-2015



<u>Source</u>: STATEC, *Statistical Yearbook*, Table A.4300 (updated 24 February 2016): http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=12771&IF_Language=fra&MainTheme=1&FldrName=4&RFPath=51

<u>Notes</u>: (1) Natural gas is expressed in GCV;
(2) from 2000 onwards, heat that is consumed by the cogeneration power plants themselves is no longer included, hence there is a break in the time series (||);
(3) only the organic fraction of waste is counted. The biogas included as renewable energy source is expressed in GCV that also comprises blended biofuels. There is a break in the time series between 1999 & 2000 (||).

Natural gas has also become the main energy source of Luxembourg's national electricity production capacity. In 1990, more than 90% of Luxembourg's electric energy consumption was imported and one medium size power plant of about 70 MW was run by the iron and steel company Arbed.[51] That power plant was mainly run on blast furnace gas – a side product of the blast furnaces in the steel industry – and was phased out in 1998 after the last blast furnace went out of service. In the early 1990s, small combined heat-power (CHP) installations (or cogeneration) plants appeared. Their installation was encouraged financially by the Government. This development was followed later by some industrial companies which installed gas turbines to produce electricity and heat simultaneously. In mid-2002, the ultra-modern TWINerg power plant started its commercial operation. Located in Esch-sur-Alzette, TWINerg is a gas and steam turbine power station running on natural gas, with an electrical output of 376 MWel (efficiency 55.7%).[52] If almost all of these cogeneration plants run on natural gas, gas oil remains the emergency fuel in case of a natural gas supply disruption.

The impact of TWINerg on the primary energy consumption mix is clearly visible in Table 2-7 and its associated Figure 2-17: electricity imports dropped and natural gas primary consumption increased in 2002, while in 2015 they reverted back to similar values than in 2001. After a few years of reduced activity, the TWINerg plant was finally shut down in 2016. To complement this analysis, an energy balance for electric power is provided (Table 2-9 & Figure 2-19).

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51 Then Arcelor and now, ArcelorMittal.

52 http://www.twinerg.lu/en_index.html, "Environment" tab and http://www.ilr.public.lu/gaz/documents/statistiques/rapport2011.pdf, p. 29.

Table 2-9 – Energy balance for electric power: 1990-2015

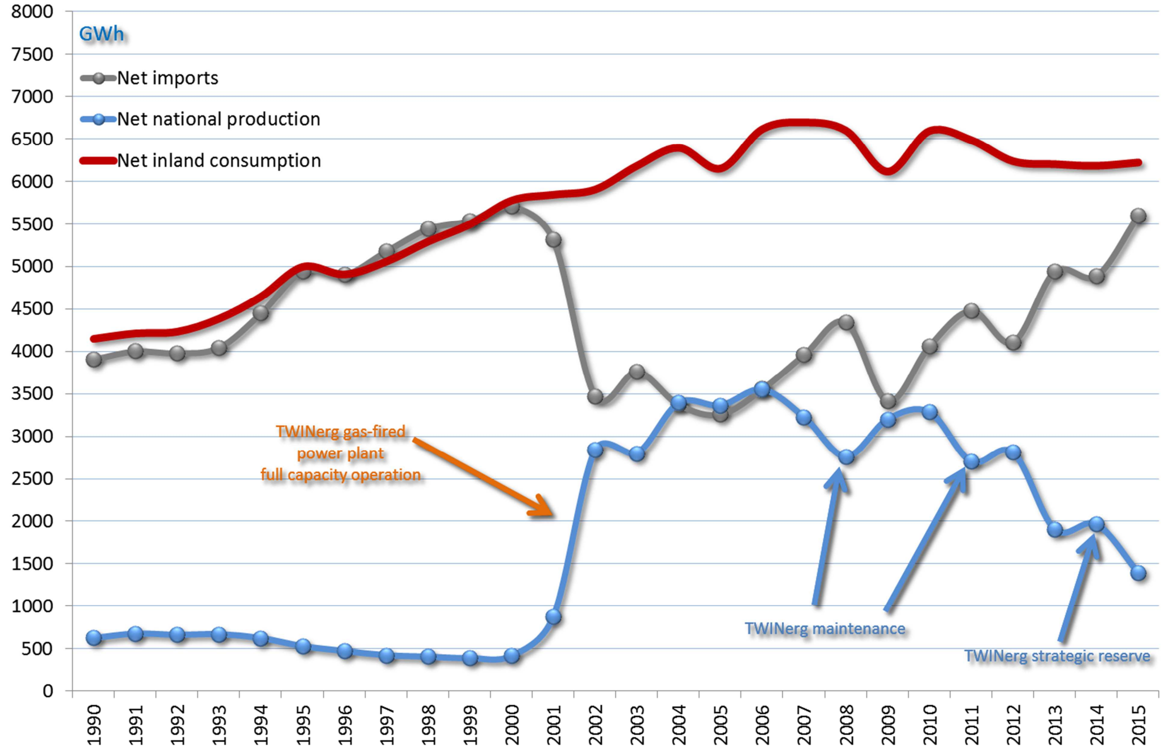
GWh	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Imports	**4665.46**	**4718.45**	**4523.56**	**4440.97**	**5015.24**	**5693.47**	**5712.33**	**6026.52**	**6366.60**	**6193.53**	**6445.38**
National production	**626.24**	**676.37**	**662.49**	**669.79**	**625.07**	**529.86**	**473.71**	**424.10**	**406.88**	**390.00**	**416.79**
cogeneration	NO	NO	NO	NO	33.00	102.00	114.00	118.00	195.00	205.00	216.48
thermic power stations	558.72	622.11	594.14	607.83	505.96	346.53	306.24	213.96	104.76	51.62	51.50
hydro-electricity	67.52	54.26	68.35	61.96	86.11	81.33	53.46	89.28	101.98	115.23	119.49
wind	NO	NO	NO	NO	NO	NO	NO	2.74	4.61	17.14	24.74
biomass & biogas	NO	NO	NO	NO	NO	NO	NO	0.12	0.52	1.01	4.54
gas from WWTPs	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
gas from landfill sites	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
photovoltaic	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.04
Total	**5291.70**	**5394.82**	**5186.04**	**5110.76**	**5640.32**	**6223.33**	**6186.04**	**6450.62**	**6773.48**	**6583.53**	**6862.17**
Exports	**754.92**	**715.17**	**542.95**	**394.41**	**565.57**	**744.15**	**808.06**	**846.96**	**924.12**	**654.97**	**736.85**
Conversion uses and losses	**389.32**	**395.43**	**334.28**	**318.06**	**364.83**	**434.15**	**431.95**	**418.98**	**428.05**	**340.97**	**359.49**
Net inland consumption	**4149.00**	**4211.00**	**4231.00**	**4385.00**	**4644.00**	**4996.00**	**4907.00**	**5057.00**	**5292.00**	**5495.00**	**5775.00**
Total	**5293.25**	**5321.59**	**5108.23**	**5097.46**	**5574.40**	**6174.30**	**6147.00**	**6322.94**	**6644.17**	**6490.94**	**6871.34**

Summary in GWh	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Net imports	**3910.54**	**4003.28**	**3980.61**	**4046.57**	**4449.67**	**4949.32**	**4904.28**	**5179.56**	**5442.48**	**5538.56**	**5708.52**
Net national production (1)	**626.24**	**676.37**	**662.49**	**669.79**	**625.07**	**529.86**	**473.71**	**424.10**	**406.88**	**390.00**	**416.79**
Net inland consumption	**4149.00**	**4211.00**	**4231.00**	**4385.00**	**4644.00**	**4996.00**	**4907.00**	**5057.00**	**5292.00**	**5495.00**	**5775.00**
Net inland consumption in Mio. MJ **(3)**	14936.40	15159.60	15231.60	15786.00	16718.40	17985.60	17665.20	18205.20	19051.20	19782.00	20790.00
Net inland consumption in 1000 toe	356.75	362.08	363.80	377.04	399.31	429.58	421.93	434.82	455.03	472.48	496.56

GWh	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Imports	**6562.18**	**6506.31**	**6391.61**	**6823.54**	**6846.58**	**6829.87**	**6022.47**	**7279.51**	**7096.34**	**6732.10**	**6851.52**
National production	**2798.99**	**3393.35**	**3363.45**	**3550.93**	**3226.13**	**2761.89**	**3201.55**	**3284.47**	**2704.70**	**2810.51**	**1904.26**
cogeneration	396.88	441.39	444.66	470.07	398.30	421.64	389.88	439.08	446.44	437.31	416.76
thermic power stations	2285.48	2787.37	2736.60	2866.49	2598.86	2089.25	2571.43	2607.40	2048.75	2103.93	1156.90
hydro-electricity	73.94	95.64	85.03	102.67	107.19	121.23	97.02	100.25	58.40	88.73	110.37
wind	26.17	39.40	52.25	57.99	64.29	60.59	63.47	55.08	64.05	77.47	83.03
biomass & biogas	15.13	20.34	27.22	32.60	36.59	43.83	53.33	55.96	55.31	57.80	56.46
gas from WWTPs	NO	NO	NO	NO	NO	5.32	5.85	5.14	6.00	6.00	6.00
gas from landfill sites	NO	NO	NO	NO	NO	NO	0.26	0.41	0.00	1.00	1.00
photovoltaic	1.40	9.20	17.70	21.11	20.90	20.03	20.32	21.15	25.74	38.28	73.74
Total	**9361.17**	**9899.66**	**9755.06**	**10374.46**	**10072.71**	**9591.76**	**9224.02**	**10563.98**	**9801.04**	**9542.60**	**8755.79**
Exports	**2799.41**	**3131.58**	**3131.31**	**3266.55**	**2886.84**	**2483.53**	**2604.48**	**3216.07**	**2614.39**	**2621.78**	**1907.52**
Conversion uses and losses	**475.68**	**366.33**	**453.13**	**472.35**	**466.47**	**474.25**	**423.09**	**674.15**	**608.00**	**593.24**	**593.24**
Net inland consumption	**6182.00**	**6393.00**	**6150.00**	**6614.00**	**6695.00**	**6598.00**	**6114.00**	**6593.00**	**6485.00**	**6236.00**	**6201.00**
Total	**9457.09**	**9890.91**	**9734.43**	**10352.90**	**10048.31**	**9555.78**	**9141.57**	**10483.22**	**9707.39**	**9451.02**	**8701.76**

Summary in GWh	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Net imports	**3762.77**	**3374.73**	**3260.30**	**3556.99**	**3959.74**	**4346.34**	**3417.99**	**4063.44**	**4481.96**	**4110.32**	**4944.01**
Net national production (1)	**2798.99**	**3393.35**	**3363.45**	**3550.93**	**3226.13**	**2761.89**	**3201.55**	**3284.47**	**2704.70**	**2810.51**	**1904.26**
Net inland consumption	**6182.00**	**6393.00**	**6150.00**	**6614.00**	**6695.00**	**6598.00**	**6114.00**	**6593.00**	**6485.00**	**6236.00**	**6201.00**
Net inland consumption in Mio. MJ **(3)**	22255.20	23014.80	22140.00	23810.40	24102.00	23752.80	22010.40	23734.80	23346.00	22449.60	22323.60
Net inland consumption in 1000 toe	531.56	549.70	528.80	568.70	575.67	567.33	525.71	566.90	557.61	536.20	533.19

Figure 2-19 –Energy balance for electric power: 1990-2015



Sources: Compiled by the Environment Agency on 25 February 2016 using data published by the Ministry of the Economy – Energy Department, the *Institut Luxembourgeois de Régulation* and STATEC (Table A.4203).

Notes: (1) The net national production is the difference between the national production and the conversion process uses and losses.
(2) Net inland consumption expressed in TJ (Mio. MJ) differs slightly from the corresponding figures in Table II.6-2 – less than 2% – because data sources, units and calculations are not exactly the same.

2.1.6 Road transportation

2.1.6.1 Diverse inland and cross-border road transport flows

Luxembourg's location and its economic development have made it a **focal point for international road traffic**. Luxembourg is located at the heart of the main traffic axes for Western Europe (Figure 2-15) and, therefore, has traditionally had a high volume of road transit traffic for both goods (freight transport) and passengers (tourists on their way to or back from southern Europe). The latter has increased even further by the **high number of commuter journeys** observed every working day. In comparison with international traffic, domestic traffic plays only a relatively small role since it responsible for only one quarter of the total road fuels sold in Luxembourg.

Road traffic is also the largest source of emissions in Luxembourg's GHG balance. Fuel quantities sold at Luxembourg's petrol stations, after having been converted into GHG volumes, are, according to IPCC reporting rules, totally included in the GHG balance, although around 75% of the emissions cannot be assigned to vehicles registered in Luxembourg and are actually emitted mostly abroad. This phenomenon is referred to as "**road fuel sales to non-residents**" whether they are in transit or commuting for work or leisure. Indeed, due to a policy of low taxed fuel (gasoline and diesel), Luxembourg is an attractive "fuelling station" for daily commuters from neighbouring countries and cross-border shoppers, but, in first instance, for international road transit traffic crossing its territory (mainly freight transport). "Road fuel sales to non-residents" is briefly defined in Box 2-2.

With numerous trucks transiting through Luxembourg, as well as a passenger cars market dominated by diesel vehicles in at least two of its neighbouring countries – namely Belgium and France – it is not surprising that diesel oil is the first liquid fuel in terms of volumes sold (Figure 2-21).

The allocation of fuel sales between residents ("domestic") and non-residents ("exports") is not made on the basis of statistics or counting, but well using the NEMO model. Details are provided in Section 3.2.8.3 of this National Inventory Report.

Box 2-2 – "Road fuel sales to non-residents"

It covers fuel sales to non-residents, *i.e.*:

1. Road vehicles in transit: freight trucks, buses & coaches, passenger cars, whose an important share fills up in Luxembourg because of lower fuel prices;
2. Cross-border commuters who are also benefiting of the cheaper fuel prices;
3. "Fuel tourism", known as "*Tanktourismus*" in Luxembourg: people driving especially to Luxembourg for benefiting of lower fuel prices, as well as lower prices on other commodities such as non-alcoholic & alcoholic drinks, tobacco, *etc.* (Luxembourg usually applies the lower taxation rates adopted at EU levels, *i.e.* 15%).

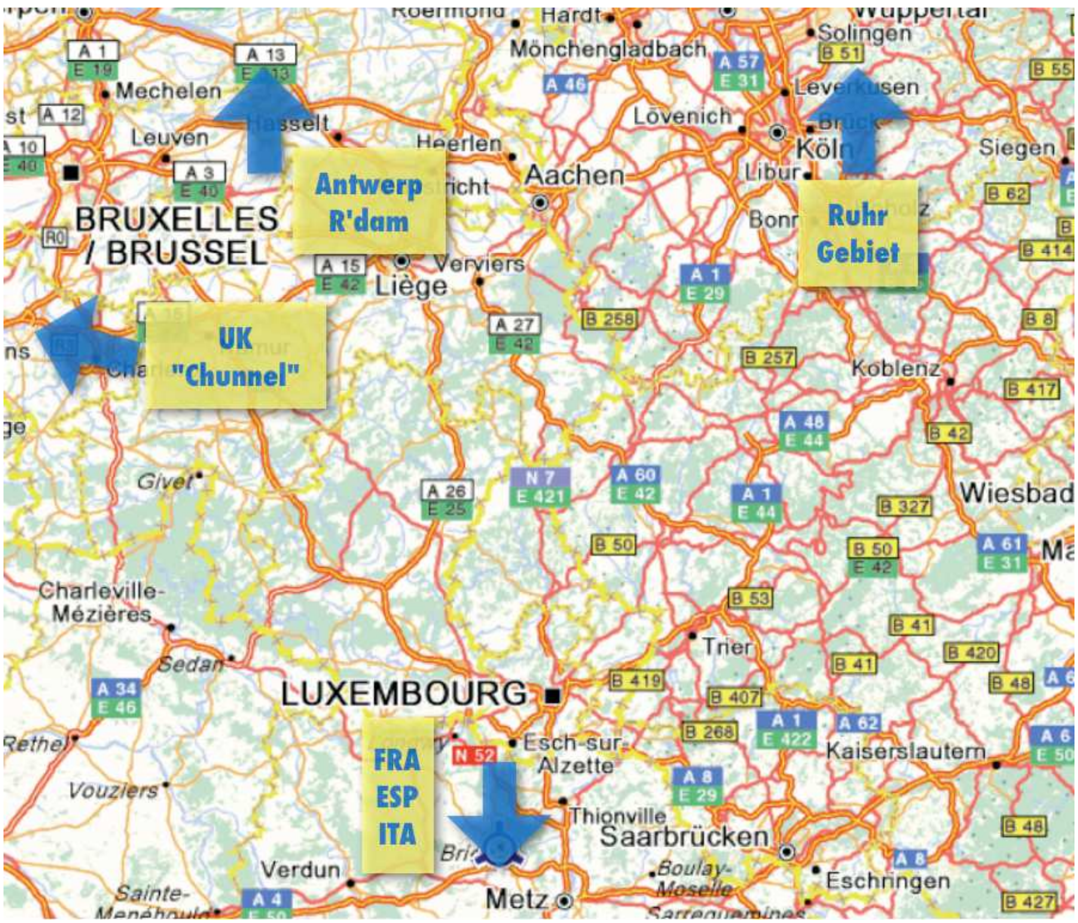
In the subsequent chapters & sections of this NIR, "road fuel sales to non-residents" is sometimes referred to as "(road) fuel exports".

2.1.6.2 Effects on GHG emissions: an untypical situation

Combining the size of the country and of its economy, on the one side, and lower road fuel prices that implies a disproportionate volume of road fuel sales compared to its resident population, on the other side, Luxembourg presents a completely untypical and unique structural feature in its GHG emissions balance. In 2015, some 5.68 Mio. t CO_2eq were produced by the road transportation sector and out of these, 4.0 Mio. t CO_2eq, corresponding to 70.0%, was the result of road fuels bought by non-residents and were, consequently, merely emitted abroad. That last amount represented around 38.8% of the total 2015 GHG emissions for Luxembourg (excluding LULUCF) while the whole CRF sub-category 1A3b accounted for 55.3% for of the total 2015 GHG emissions for Luxembourg (excluding LULUCF) (Figure 2-22).

Both emissions generated by the national vehicles fleet and by the non-residents – "road fuel sales to non-residents" – showed dramatic increases over the period: +97.4% and +135.2% respectively.[53] For the national fleet, the evolution is correlated with both the population and economic activity growth. It is also explained by an increasing rate for passenger cars per inhabitants (from 477 to 662 passenger cars per 1000 inhabitants between 1990 and 2014, *i.e.* the highest rate within the EU[54]). Regarding "road fuel sales to non-residents", the rise is undoubtedly linked to the growing number of commuters crossing the borders every working day as well as to the general increase of road freight traffic in Europe.

Figure 2-20 – MAIN ROAD FREIGHT AXES CROSSING LUXEMBOURG



<u>Source:</u> ViaMichelin.

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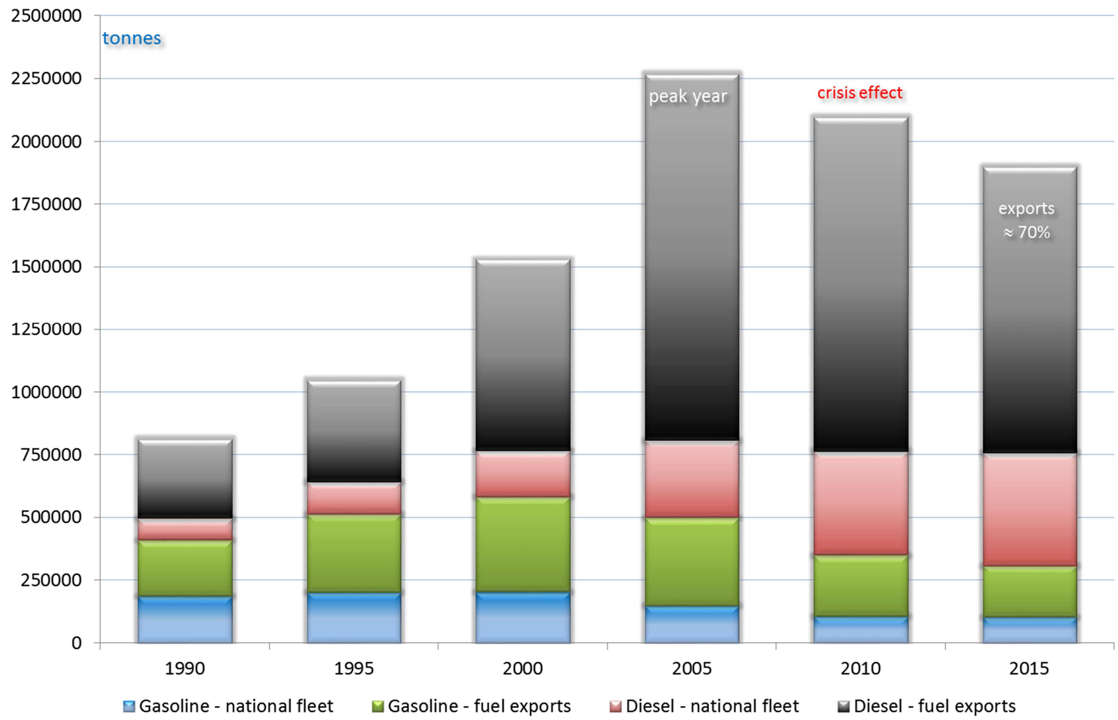
53 Corresponding percentages were +66.25% and +208% in 2005, the peak year with regard to road transportation related emissions. These percentages differ slightly from those reported under Table 3-52 since the latter includes CO_2 emissions from biomass which is not counted here.

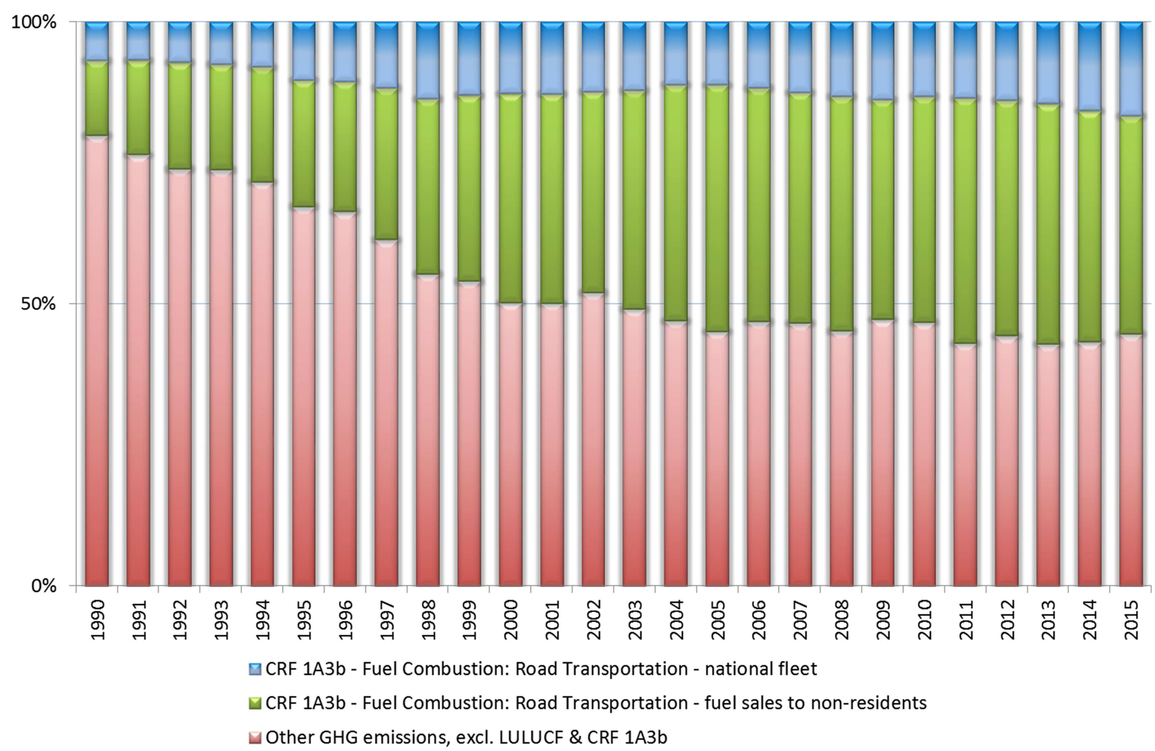
54 Data extracted from European Commission (DG MOVE), *EU Transport in figures – statistical pocketbook 2016*, p.86: http://ec.europa.eu/transport/sites/transport/files/pocketbook2016.pdf.

Figure 2-21 – Road blended fuel sales: 1990-2015 in tonnes



Source: based on Table 3-51 in Section 3.2.8.3.

Figure 2-22 – GHG emissions for road transportation (CRF sub-category 1A3b): 1990-2015



Source: Submission 2016v1.1.
Note: CO_2 emissions from biofuels are excluded, and reported as "memo item".

2.1.7 UNFCCC and Kyoto Protocol: a demanding challenge for Luxembourg

2.1.7.1 The road transportation dilemma

Since Luxembourg is a small open economy integrated in the European internal market **where mobility of tax bases are likely to be high**, only marginal variations in the price differentials for petrol and diesel can be initiated by the authorities. Indeed, if Luxembourg's rates of taxation and prices were higher than those in the surrounding countries, it would be rather easy for any citizen of Luxembourg to avoid domestic taxation and to practise arbitrage: no location in Luxembourg is further than a maximum of 25-30 km away from a border with a neighbouring country. Lower taxation rates for certain goods – such as fuels, *e.g.* – have therefore always been part of Luxembourg fiscal policy and will remain crucial in the future, because of the country's geographical location and its small area. Whereas in larger neighbouring states, increasing certain tax rates would result in a slight shift in demand and in arbitrage deals at the outer fringes of their national territory – with a corresponding relatively slight reduction in tax revenues – this would not be the case for Luxembourg where such a policy may result in big losses in tax incomes. However, since road transportation, and more precisely "road fuel sales to non-residents", is the main contributor to GHG emissions in Luxembourg, as underlined in the new national "*Action Plan for reducing CO_2 emissions*" adopted in May 2013,[55] Luxembourg will use a policy mix of instruments with the aim of progressively reducing road transport related emissions.

With regard to the instrument of excise duties, Luxembourg will gradually increase road fuels excise rates following a cautious approach based on a better knowledge of the factors determining road fuel sales in Luxembourg that also takes into account the impact on the public finances of the country. Furthermore, the new Government that took office early December 2013 underlines in its programme that a **feasibility study on the progressive way out of "fuel tourism"** – and more generally of "road fuel sales to non-residents" – should be realized so to evaluate the economic impacts of such a decision on the medium and long terms. Definitely, a long term planning of a gradual "decoupling" of road fuel sales revenues from public current expenditure is necessary; all of this taking place in an overall context of future regulatory changes in Europe that will affect other national fiscal incomes.[56] As a first step and provided that the public finance situation allows it, the programme suggests that current expenditures will no longer be financed by additional tax revenues on road fuel sales and that these revenues should progressively be reallocated to measures aiming at an energy transition towards a more sustainable economic and social model – gradual decoupling of road fuel sales revenues from public current expenditure.

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55 http://www.environnement.public.lu/actualites/2013/05/plan_action_climat/index.html.

56 For instance, since 2015 two major changes have impacted Luxembourg's economic activities: (i) modifications of banking practices and rules; (ii) the payment of the VAT in the consumption country for goods and services bought on the internet and no longer in the country where the merchant is located.

With regard to other instruments, the new Luxembourg Government considers the organization of transport and the necessity to overcome existing problems linked to the traffic intensity as primary objectives. In this context, it intends to promote sustainable ways of transport consisting of public and non-motorized modes of transport. The re-organisation is intended to encompass both the national territory and the neighbouring regions of Germany, France and Belgium where many commuters come from, leading to a doubling of the workforce in Luxembourg during the day. All this is intended to be done in a conceptual way where new modes of transport such as electro-mobility and car sharing are potentially promoted.

2.1.7.2 Country and economy sizes

Special attention must also be made for the **small size of the country's economy** in a different context: it is a contributory factor to the fact that, in spite of the healthy economic situation, the courses of the overall development of the country, of the demand for energy and of the emissions balance are often affected by a single plant which is starting its activities, closing them down or changing its production processes. This became particularly clear when the steel industry switch from blast furnaces to electric arc furnaces was completed during the 1990s: from 1990 to 1998, GHG emissions in Luxembourg were reduced by one third (see Section 2.4 for details).

Furthermore, the construction of a single power station, the TWINerg gas and steam plant, represents a further illustrative example as depicted in Section 2.1.5. When TWINerg started its operation in mid-2002, Luxembourg, which did not have so far any substantial electricity generating capacity, saw, at once, its GHG emissions increasing by 0.9 to 1 Mio. t CO_2e per year. To give another illustration on how this project affected the GHG emissions pattern in Luxembourg, one can underline that it represents 35% of the allocated emissions volume of the whole GHG EU Emissions Trading Scheme sector (EU-ETS) for the first commitment period under the Kyoto Protocol.

The impact that single industrial projects might have, plays also the other way round when a production unit or a plant is closed down. After a few years of reduced activity, the TWINerg power plant was finally shut down in 2016, which is expected to have a very high impact on Luxembourg's total GHG emissions. Also, a sufficiently long breakdown in one of the main industrial unit of the country could have impacts on the total GHG emissions, such as the long maintenance operations of the TWINerg plant in 2008 and 2011 demonstrated (cf. Figure 2-19).

If these issues might not be a major concern for large economies, it is for Luxembourg, as shown by the examples discussed above.

2.1.7.3 Limited GHG emissions reduction potentials

As of today, Luxembourg **does not have those significant technical potentials** which exist in other countries where residual "old-technology" industrial and power plants still operate. In

Luxembourg, there were almost none, and there still is none of those GHG reduction potentials stemming from the modernisation or the replacement of existing national industrial or power plants. In fact, with the move from blast to electric arc furnaces in the steel sector during the 1990s, Luxembourg very soon exhausted its only major technical potential for GHG emissions reduction. With the process change in the steel industry – an activity which accounted for almost 50% of Luxembourg's total GHG emissions in 1990 (excluding LULUCF)[57] – total emissions from industry and electricity generation – *i.e.* largely the sectors covered by the EU-ETS – decreased to just 1.08 Mio. t CO_2e in 2015 – or 10% of total GHG emissions (excluding LULUCF) – coming from slightly more than 6.3 Mio. t CO_2e in 1990 - or about 49% of total GHG emissions (excluding LULUCF).[58]

Also, any ultramodern fossil fuel-based electricity generating plant that Luxembourg might decide to construct will automatically lead to an increase of its national GHG emissions, since there are no existing power plants which can be stopped in return. Thus, those highly efficient CHP installations and the ultramodern gas and steam power station (TWINerg, shut down in 2016) that have been promoted and are operating in Luxembourg since 1998, and that use natural gas and, sometimes, gas oil as inputs, have led to an additional amount of approx. 1.2 Mio. t CO_2e per year in the GHG balance.[59] It is therefore clear that any new fossil-fuel power generating installation that might be constructed will inevitably lead to a deterioration of Luxembourg's GHG balance. This also implies that the implementation of the EU CHP installation guidelines, which in other countries may lead to CO_2 reductions thanks to increased efficiency, is counterproductive for Luxembourg. For this reason, Luxembourg's authorities will only promote heat production from renewable energy sources, focusing mainly on biomass, wood and solar energy.[60] More precisely, CHP installations using renewable energies, biogas addition in distribution networks and the mobilization of wood resources will be favoured.

2.1.7.4 The "origin" principle of the IPCC reporting Guidelines vs. "polluter pays" principle

For the period 2002-2012, the "origin" or "territorial" principle applied for reporting GHG emissions under the IPCC Guidelines generates a GHG balance for Luxembourg that looks significantly less favourable than would a "consumer" or "polluter pays" approach produce (Figure 2-23). The "origin" principle is in favour of Luxembourg in that its imports of electricity are excluded from its GHG emission balance: those emissions are attributed to the electricity

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57 Sum of CRF sub-categories 1A2a and 2C1. This percentage is 3.47% for 2014.

58 Sum of CRF sub-categories 1A1a, 1A2 and 2, excluding F-gases. The lowest share (18.3%) was obtained in 2013 – and the lowest absolute value (1.7 Mio. t CO_2e) in 1998.

59 1 Mio. t CO_2e for the TWINerg and 0.2 Mio. t CO_2e for CHP installations.

60 See the second *Action Plan for Reducing CO_2 Emissions* (http://www.environnement.public.lu/actualites/2013/05/plan_action_climat/index.html).

producing countries. But, as indicated above, "road fuel sales to non-residents" related emissions are reported in Luxembourg's GHG balance.

Now, if the "polluter pays" principle is used as a yardstick, Luxembourg's assessment reveals that GHG emissions according to the IPCC Guidelines are higher from 2002-2012 (the period during which the TWINerg power plant was fully operational), but about 1.6 Mio. t CO_2e lower for 2015 (Figure 2-23).[61] This illustrates that the presence of a single power plant – even though it was highly efficient – has a significant impact on Luxembourg's national total GHG emissions.

Thus, Luxembourg's efforts to develop efficient, low-carbon electricity production are not rewarded in the actual reporting system for GHG emissions. Luxembourg has, for many years, promoted the construction and the development of highly efficient CHP installations and of a modern gas and steam power plant. Luxembourg has also actively supported power generation and uses based upon renewable energies and, for all these policies, further developments are still in the offing. The impact of these policies has been evaluated using GEMIS 4.2:[62] it has been estimated that electricity net imports – with, nowadays, an average emission factors of 0.75 (kt CO_2 per GWh) – have fallen by more than 1 200 GWh since 2001 – the last year before the TWINerg power plant operated at full capacity – and have been replaced by national electricity generation with a current average emission factor of 0.41 (kt CO_2 per GWh).

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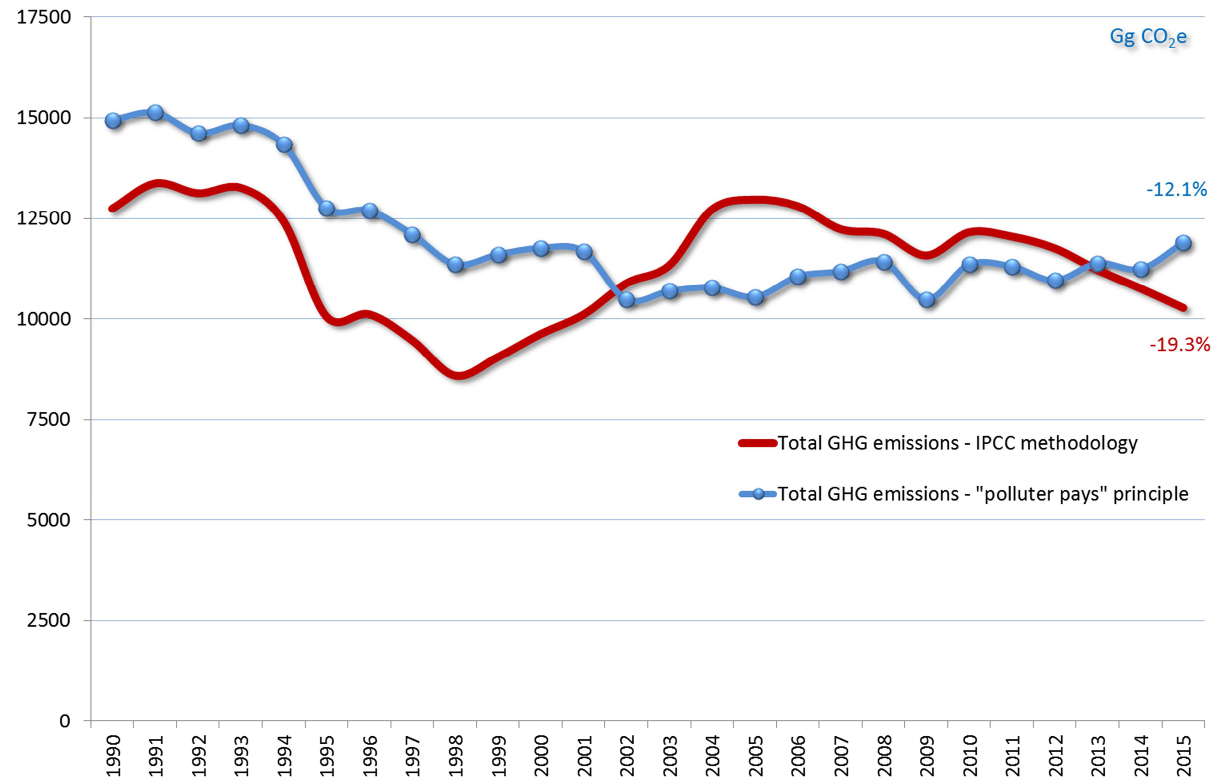
61 After having reached a "surplus" of 1.8 Mio. t CO_2e in 2005.

62 GEMIS stands for *Global Emission Model for Integrated Systems*: http://www.iinas.org/gemis-de.html.

Figure 2-23 – Total GHG emissions, excluding LULUCF – two approaches: 1990-2015



Sources: Environment Agency and MDDI-DEV.

Notes: The "polluter pays" principle figures have been obtained from the total GHG emission according to the IPCC methodology by excluding emissions from "road fuel sales to non-residents" and for electricity generated that is exported, and by adding an estimate for electricity production emissions generated abroad for satisfying Luxembourg consumption (*i.e.* emissions relating to electricity imports):
Emissions "polluter pays" principle = emissions IPCC methodology – emissions "road fuel sales to non-residents" + emissions electricity net imports

So, in terms of the GHG balance, the promotion of renewable energies in the electricity sector, which is associated with major investments, is of little interest. Moreover, additional capacities based upon renewable energies cannot actually be used to replace any electricity from inefficient existing fossil-fuel plants in Luxembourg. Nor will they substitute the modern and highly efficient national production plants. In reality, they will replace the imported electricity which does not contribute to Luxembourg's GHG balance. In this sense, the existing system provides Luxembourg with the incentive not to earmark the generally scant subsidies for Europe's priority investments in renewable energies but, instead, to invest these in measures which might improve its GHG balance.

2.1.8 National circumstances: overview

Key points that play a role on GHG emissions trends in the past and in the future are:

- a country characterized by both **high demographic** and **high economic growth** in a stagnating region, hence an **attractive economic destination**;

- **strong population growth** due to immigration and that is expected to go on;
- **even stronger cross-border commuters growth** that is expected as well to go on once the financial and economic crisis will be over;
- **increase of built-up areas** (housing, offices, services, infrastructures) as a consequence of the previous statements;
- location at the **heart** of the main Western Europe **transit routes** for both **goods and passengers**;
- **increase of transport flows** as a consequence of the previous statements;
- **small size** and open economy: a new industrial project, a technological change, a closure or a breakdown of a production unit might have significant impacts on the GHG emissions and increase the overall uncertainty of GHG projections;
- **limitations in taxation policies** due to short distances to neighbouring countries;
- a country that **needs to co-operate and to interact with its neighbours** since environmental issues become quickly cross-border issues;
- **limited national** GHG emissions reduction potential.

Figure 2-24, Figure 2-25 and Figure 2-26 provide a quick overview of the trends of some key variables since 1990.

Figure 2-24 – Key variables trends – 1: 1990-2015

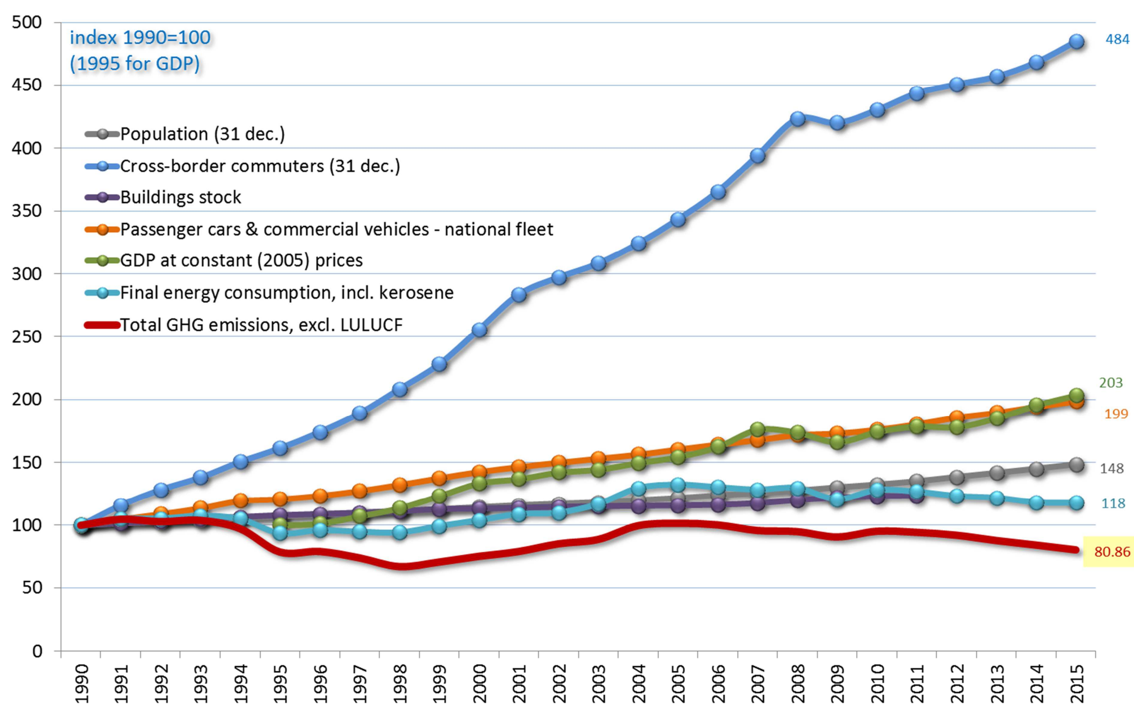


Figure 2-25 – Key variables trends – 1: 1990-2015 (excl. cross-border commuters)

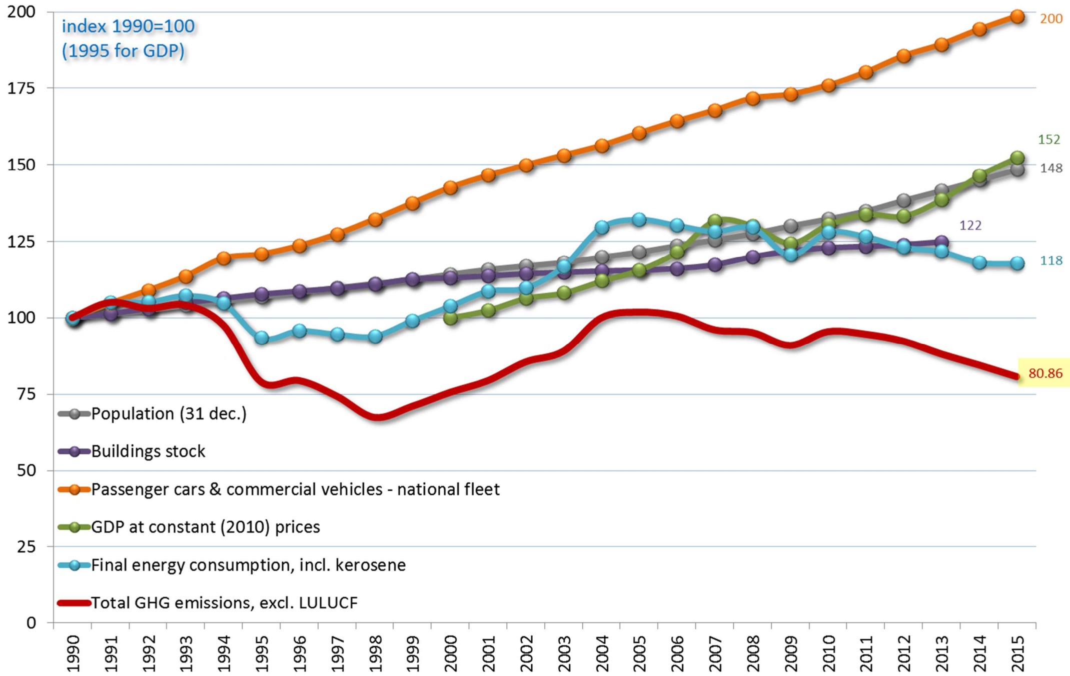
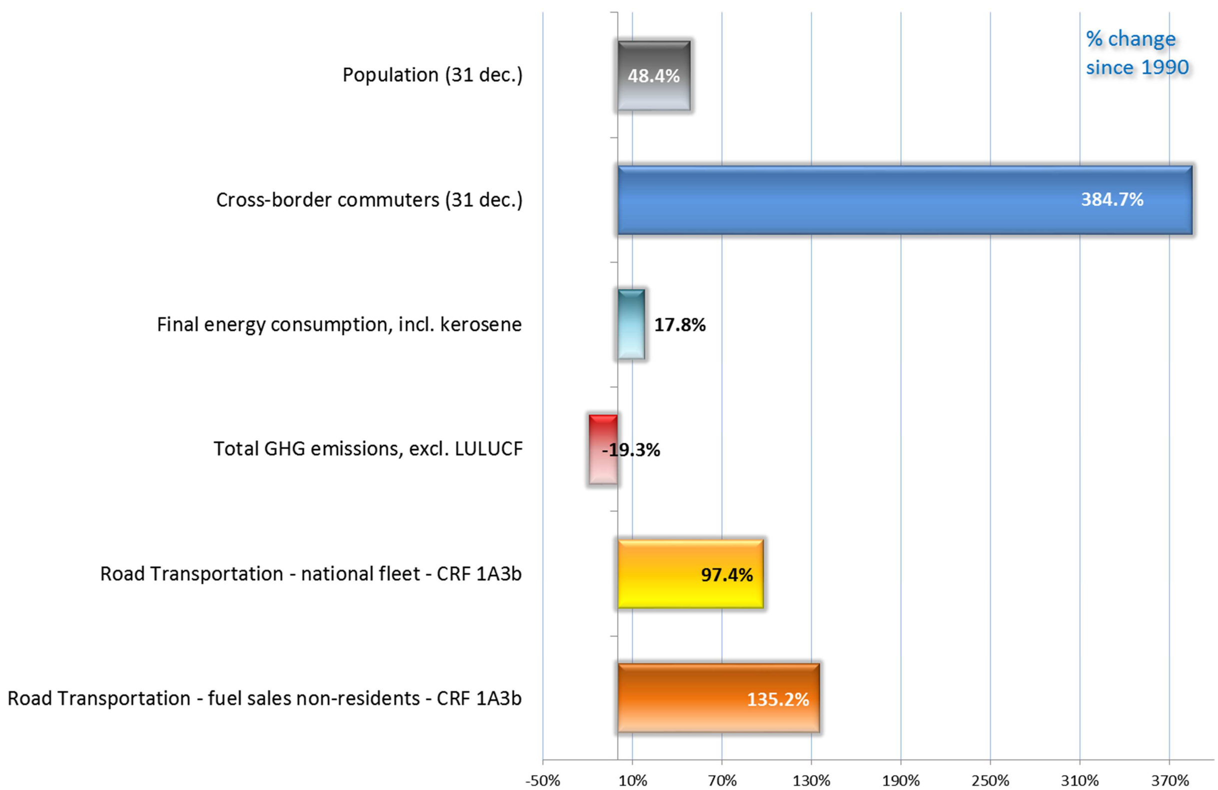


Figure 2-26 – Key variables trends – 2: 1990 & 2015



Sources: Population: STATEC, *Statistical Yearbook*, Table B.1100 (updated 31 March 2017).
http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=12856&IF_Language=fra&MainTheme=2&FldrName=1
Commuters: STATEC, *Statistical Yearbook*, Table B.3107 (updated 31 March 2017).
http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=12928&IF_Language=fra&MainTheme=2&FldrName=3&RFPath=92
Buildings stock: MDDI-DEV estimates on the basis of STATEC, *Statistical Yearbook*, Table D.4200 & results from the 2011 population census.
http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=13443&IF_Language=fra&MainTheme=4&FldrName=4&RFPath=35
http://www.statistiques.public.lu/stat/tableviewer/document.aspx?ReportId=8624
Cars & vehicles: STATEC, *Statistical Yearbook*, Table D.6102 (updated 31 March 2017).
http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=13499&IF_Language=fra&MainTheme=4&FldrName=7&RFPath=7049%2c13898

GDP: STATEC, *Statistical Yearbook*, Table E.2101 (updated 31 March 2017).
http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=13147&IF_Language=fra&MainTheme=5&FldrName=2&RFPath=23
Energy: STATEC, *Statistical Yearbook*, Table A.4300 (updated 31 March 2017).
http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=12771&IF_Language=fra&MainTheme=1&FldrName=4&RFPath=51
GHG: Environment Agency and MDDI-DEV – Submission 2016v1.1.

Notes: (1) Energy: there is a break in time series between 1999 & 2000.
(2) Buildings stocks = stock of permanently occupied dwellings.

2.2 Description of Emission Trends for Aggregated GHG Emissions

Luxembourg ratified the United Nations Framework Convention on Climate Change in 1994, and the Kyoto Protocol in 2002. Pursuant to that Protocol and the terms of the European agreement distributing the burden among, at that time, the EU-15 Member States, Luxembourg committed itself **to reduce its GHG emissions by 28% below their 1990 level over the period 2008-12**. This is the deepest cut of any agreed by the 15 Member States. When the Act approving the Kyoto Protocol was adopted in Luxembourg (2001), its GHG emissions were down by more than 30% between 1990 and 1998 (Table 2-10). Now for the 2nd commitment period EU Member States aim to reduce GHG emissions by 20% with regard to the reference year 1990.

In 2015, carbon dioxide was the main source of GHG in Luxembourg. This source counted for 90.6% of the total GHG emissions calculated in CO_2e – total excluding LULUCF.[63] The second source of GHG was methane with 6.1% of the total GHG emissions. Nitrous oxide was the third source with 2.6%. Fluorinated gases only accounted for 0.74% of the total GHG emissions, with hydrofluorocarbons representing 0.6% of the total GHG emissions and sulphur hexafluoride representing 0.09% of the total GHG emissions.

In 2015, total GHG emissions amounted to 10.3 Mio. t CO_2e, 19.3% below their level in 1990 and 19.5% below the level retained for the base year under the Kyoto Protocol.[64] As Figure 2-27 shows, several phases can clearly be distinguished over the period 1990 to 2015:

- firstly, from base year up to 1993, Luxembourg's emissions remained rather stable;

63 In Section 2.2, "total (GHG) emissions" mean "total GHG emissions excluding LULUCF". Reference is made to total emissions excluding LULUCF since this is the one that counts for the reduction target under the Kyoto Protocol.

64 The level of emissions considered for the base year is 12.749 Mio. t CO_2e. The base year for CO_2, CH_4 and N_2O is 1990. For the F-gases, the base year is 1995. When the assigned amount under the Kyoto Protocol was determined, F-gases emissions were equal in 1990 and 1995 due to a lack of background data and methods at that time. Now, as Table 2-10 shows, F-gases emissions are no longer the same in 1990 and 1995.

- then, between 1994 and 1998, they started to decrease significantly to reach their lowest value in 1998, when they were down by more than 30%;
- from 1999 up to 2004, emissions augmented recurrently;
- from 2004 to 2006, a stabilisation peaking around 13 Mio. t CO_2e is observed;
- a decrease occurred between 2006 and 2007 followed by a period of two years impacted by the financial and economic crisis.

The evolution during those 25 years can essentially be explained by **changes in production techniques**, as well as by **changes in the final "energy-mix" consumption**. Of course, **increasing or decreasing activities** for certain source categories also played a crucial role in Luxembourg's GHG emissions trend. During the years 2008-2010, **the financial and economic crisis and its aftermaths** also played a part. The decreasing trend in emissions since 2012 is mainly due to the progressive shutdown of the TWINerg power plant and slowly declining sales of road fuels.

Table 2-10 – Luxembourg's GHG emissions and removals – overview by main gases and CRF Sectors: 1990-2015

Gg (1000 t.) CO_2 equivalent	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
CO_2 emissions, incl. net CO_2	11839.06	12177.98	11609.42	11653.46	11030.92	8536.07	8542.35	7811.50	7043.50	7397.32	7950.14	8431.72	9206.90
from LULUCF (1)	92.67%	92.72%	92.45%	92.50%	92.29%	90.05%	89.95%	89.10%	88.04%	88.45%	89.22%	89.84%	90.59%
CO_2 emissions, excl. net CO_2	11812.05	12428.21	12188.83	12327.93	11516.20	9124.44	9171.13	8523.01	7639.44	8090.96	8673.16	9166.12	9942.38
from LULUCF	92.79%	92.98%	92.90%	93.00%	92.72%	90.79%	90.73%	90.08%	89.05%	89.50%	90.19%	90.73%	91.37%
CH_4 (2) emissions, incl. net CH_4	634.97	641.56	630.76	629.56	605.20	620.68	630.29	631.08	628.50	633.85	626.10	630.97	630.42
from LULUCF (1)	4.97%	4.88%	5.02%	5.00%	5.06%	6.55%	6.64%	7.20%	7.86%	7.58%	7.03%	6.72%	6.20%
CH_4 (2) emissions, excl. net CH_4	634.97	641.56	630.76	629.56	605.20	620.68	630.29	631.08	628.50	633.85	626.10	630.97	630.42
from LULUCF	4.99%	4.80%	4.81%	4.75%	4.87%	6.18%	6.24%	6.67%	7.33%	7.01%	6.51%	6.25%	5.79%
N_2O (3) emissions, incl. net N_2O	303.89	317.26	307.15	303.89	302.49	306.43	306.63	304.23	305.22	307.88	307.21	290.48	289.82
from LULUCF (1)	2.38%	2.42%	2.45%	2.41%	2.53%	3.23%	3.23%	3.47%	3.82%	3.68%	3.45%	3.10%	2.85%
N_2O (3) emissions, excl. net N_2O	282.56	295.94	285.82	282.57	281.17	285.11	285.31	282.91	283.90	286.56	286.21	269.79	269.45
from LULUCF	2.22%	2.21%	2.18%	2.13%	2.26%	2.84%	2.82%	2.99%	3.31%	3.17%	2.98%	2.67%	2.48%
HFCs (4)	0.00	0.00	13.68	14.70	15.98	18.31	20.06	22.54	24.98	26.78	29.58	33.49	36.38
	0.00%	0.00%	0.10%	0.11%	0.13%	0.18%	0.20%	0.24%	0.29%	0.30%	0.31%	0.33%	0.33%
PFCs (4)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SF_6 (4)	0.88	0.98	1.08	1.19	1.30	1.39	1.56	1.70	1.74	1.83	1.93	2.54	3.15
	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.02%	0.02%	0.02%	0.02%	0.02%	0.03%	0.03%
1. Energy	10263.87	10966.43	10801.12	10965.53	10247.29	8214.19	8319.54	7780.67	7055.50	7472.60	8030.26	8584.48	9355.53
	80.62%	82.04%	82.32%	82.72%	82.51%	81.73%	82.30%	82.24%	82.25%	82.66%	83.50%	84.97%	85.97%
2. Industrial Processes	1640.25	1561.67	1503.97	1481.51	1389.81	1031.71	977.24	869.97	711.96	750.89	779.35	725.92	746.81
	12.88%	11.68%	11.46%	11.18%	11.19%	10.27%	9.67%	9.20%	8.30%	8.31%	8.10%	7.19%	6.86%
3. Agriculture	714.41	724.90	701.13	694.30	676.37	697.77	704.09	700.39	698.93	704.84	695.38	681.24	667.34
	5.61%	5.42%	5.34%	5.24%	5.45%	6.94%	6.97%	7.40%	8.15%	7.80%	7.23%	6.74%	6.13%
4. LULUCF	44.42	-232.82	-562.00	-657.06	-467.88	-570.96	-611.38	-694.11	-578.53	-676.24	-705.87	-717.51	-718.84
	0.35%	-1.74%	-4.28%	-4.96%	-3.77%	-5.68%	-6.05%	-7.34%	-6.74%	-7.48%	-7.34%	-7.10%	-6.61%
5. Waste	111.92	113.69	113.95	114.60	106.38	106.25	107.48	110.21	112.16	111.66	111.98	111.29	112.10
	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total GHG including LULUCF	12774.88	13133.86	12558.17	12598.88	11951.97	9478.97	9496.97	8767.14	8000.02	8363.75	8911.10	9385.41	10162.93
	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Total GHG excluding LULUCF	12730.46	13366.69	13120.17	13255.94	12419.85	10049.92	10108.35	9461.25	8578.56	9039.99	9616.97	10102.92	10881.78
	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Gg (1000 t.) CO_2 equivalent	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
CO_2 emissions, incl. net CO_2	9713.87	11084.28	11389.31	11309.69	10798.23	10647.21	10131.58	11015.36	10797.45	10440.30	9716.02	9326.83	8887.60
from LULUCF (1)	91.27%	92.12%	92.43%	92.39%	91.92%	91.65%	91.26%	91.84%	91.78%	91.69%	91.02%	90.58%	90.12%
CO_2 emissions, excl. net CO_2	10411.66	11785.51	12044.64	11882.64	11290.95	11155.91	10616.84	11184.97	11088.43	10816.35	10266.72	9797.16	9305.96
from LULUCF	91.94%	92.67%	92.93%	92.85%	92.36%	92.11%	91.74%	92.06%	92.08%	92.06%	91.58%	91.09%	90.62%
CH_4 (2) emissions, incl. net CH_4	618.77	614.43	612.34	609.15	620.07	631.34	632.38	633.18	608.81	598.19	602.96	614.86	621.50
from LULUCF (1)	5.81%	5.11%	4.97%	4.98%	5.28%	5.43%	5.70%	5.28%	5.17%	5.25%	5.65%	5.97%	6.30%
CH_4 (2) emissions, excl. net CH_4	618.77	614.43	612.34	609.15	620.07	631.34	632.38	633.18	608.81	598.19	602.96	614.86	621.50
from LULUCF	5.46%	4.83%	4.72%	4.76%	5.07%	5.21%	5.46%	5.21%	5.06%	5.09%	5.38%	5.72%	6.05%
N_2O (3) emissions, incl. net N_2O	271.52	291.90	278.96	277.31	280.05	286.78	283.86	288.25	297.65	284.34	288.31	282.47	278.98
from LULUCF (1)	2.55%	2.43%	2.26%	2.27%	2.38%	2.47%	2.56%	2.40%	2.53%	2.50%	2.70%	2.74%	2.83%
N_2O (3) emissions, excl. net N_2O	251.46	272.16	259.54	258.21	261.26	268.70	266.50	271.49	281.56	268.89	273.54	268.39	265.56
from LULUCF	2.22%	2.14%	2.00%	2.02%	2.14%	2.22%	2.30%	2.23%	2.34%	2.29%	2.44%	2.50%	2.59%
HFCs (4)	38.70	40.78	39.79	42.77	47.37	49.77	51.16	53.46	56.34	58.73	62.36	67.12	67.03
	0.34%	0.32%	0.31%	0.33%	0.39%	0.41%	0.44%	0.44%	0.47%	0.50%	0.56%	0.62%	0.65%
PFCs (4)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SF_6 (4)	3.73	4.28	4.85	5.27	5.69	6.10	6.49	6.87	7.31	7.68	8.05	8.44	8.89
	0.03%	0.03%	0.04%	0.04%	0.05%	0.05%	0.06%	0.06%	0.06%	0.07%	0.07%	0.08%	0.09%
1. Energy	9880.33	11203.15	11487.42	11277.84	10693.98	10618.52	10148.88	10703.60	10588.26	10379.26	9842.25	9359.67	8869.05
	87.25%	88.09%	88.63%	88.12%	87.47%	87.67%	87.69%	88.10%	87.92%	88.34%	87.77%	87.02%	86.37%
2. Industrial Processes	694.04	754.04	725.49	779.76	775.92	721.51	651.30	675.52	692.17	632.90	616.96	633.08	626.08
	6.13%	5.93%	5.60%	6.09%	6.35%	5.96%	5.63%	5.56%	5.75%	5.39%	5.50%	5.89%	6.10%
3. Agriculture	633.59	647.20	635.84	627.26	641.42	655.35	658.86	668.17	662.00	642.50	658.25	666.53	680.83
	5.59%	5.09%	4.91%	4.90%	5.25%	5.41%	5.69%	5.50%	5.50%	5.47%	5.87%	6.20%	6.63%
4. LULUCF	-681.42	-685.12	-639.48	-557.35	-477.38	-493.94	-471.09	-155.93	-277.84	-363.44	-538.64	-458.83	-407.41
	-6.02%	-5.39%	-4.93%	-4.35%	-3.90%	-4.08%	-4.07%	-1.28%	-2.31%	-3.09%	-4.80%	-4.27%	-3.97%
5. Waste	116.36	112.77	112.43	113.17	114.02	116.45	114.33	102.68	100.02	95.19	96.18	96.69	92.97
	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total GHG including LULUCF	10642.91	12032.04	12321.70	12240.69	11747.96	11617.88	11102.28	11994.04	11764.60	11386.41	10674.99	10297.13	9861.53
	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Total GHG excluding LULUCF	11324.32	12717.16	12961.17	12798.04	12225.34	12111.83	11573.37	12149.97	12042.45	11749.85	11213.64	10755.97	10268.93
	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Source: Environment Agency and MDDI-DEV.

Notes: (1) These percentages are relative to the total GHG emissions, including LULUCF.

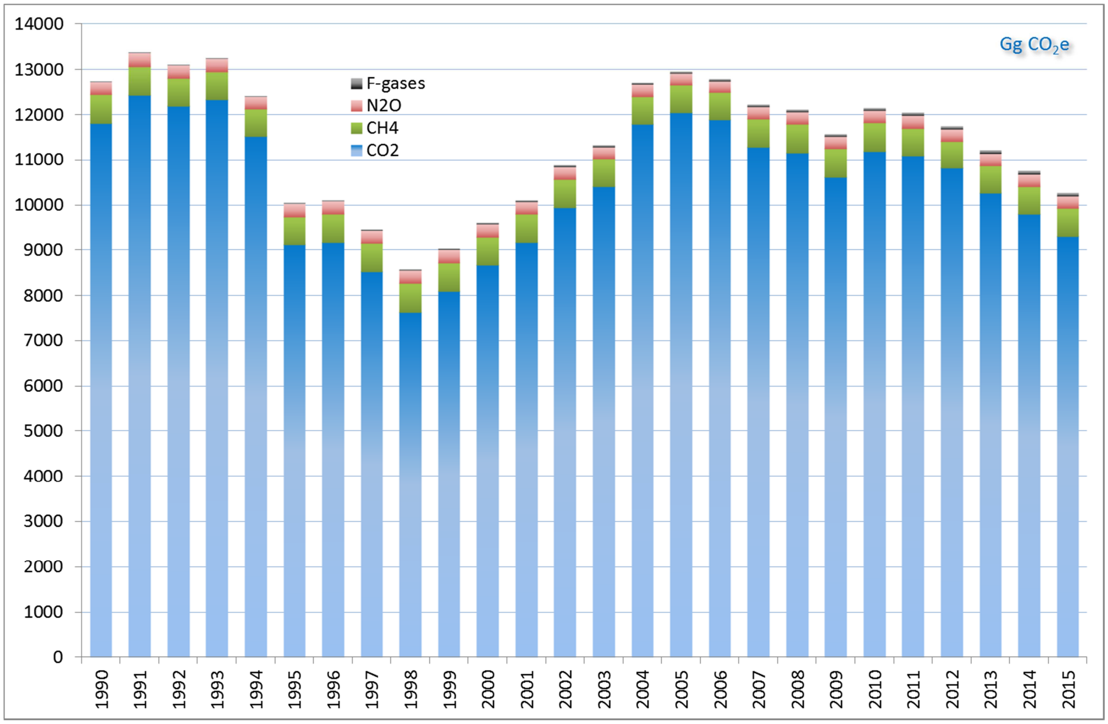
(2) The methane emissions are converted in CO_2 equivalents by multiplying the emissions by 25, *i.e.* the global warming potential (GWP) value for methane based on the effects of GHG over a 100-year time horizon.

(3) The nitrous oxide emissions are converted in CO_2 equivalents by multiplying the emissions by 298, *i.e.* the global warming potential (GWP) value for nitrous oxide based on the effects of GHG over a 100-year time horizon.

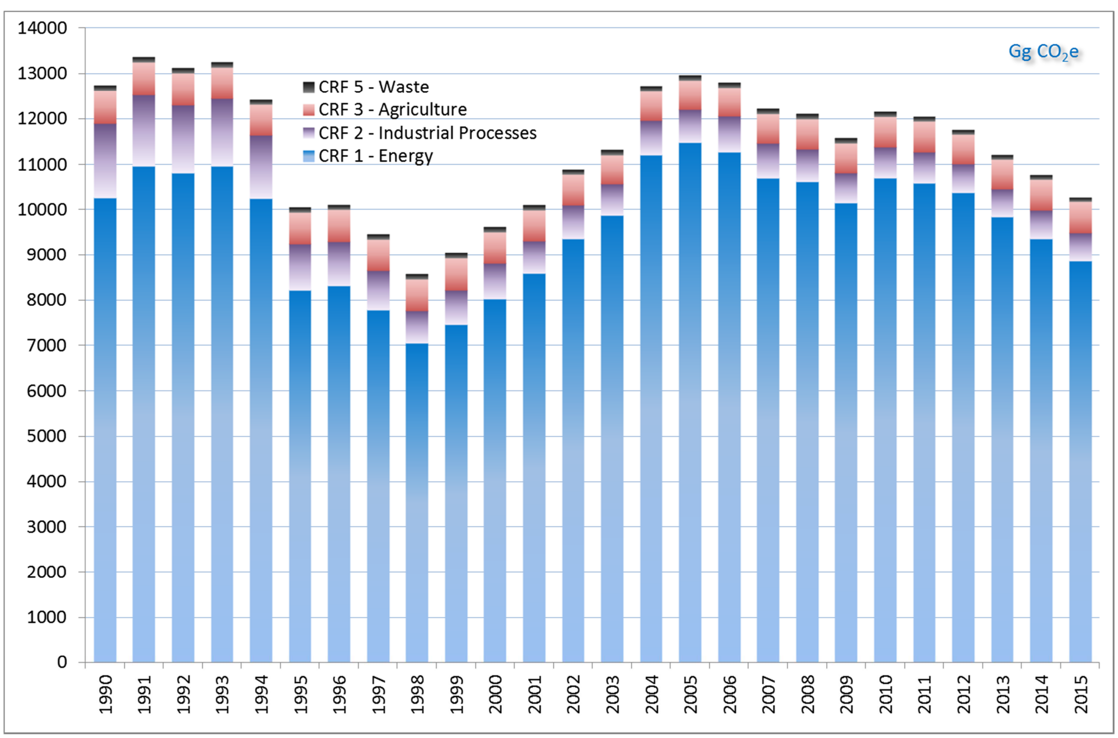
(4) The F-gases are those not covered by the Montreal Protocol, *i.e.* the HFCs, PFCs and SF_6 expressed in CO_2 equivalents using the global warming potential (GWP) values based on the effects of GHG over a 100-year time horizon.

Figure 2-27 – Luxembourg's GHG emissions (excl. LULUCF) – absolute values: 1990-2015

GHG



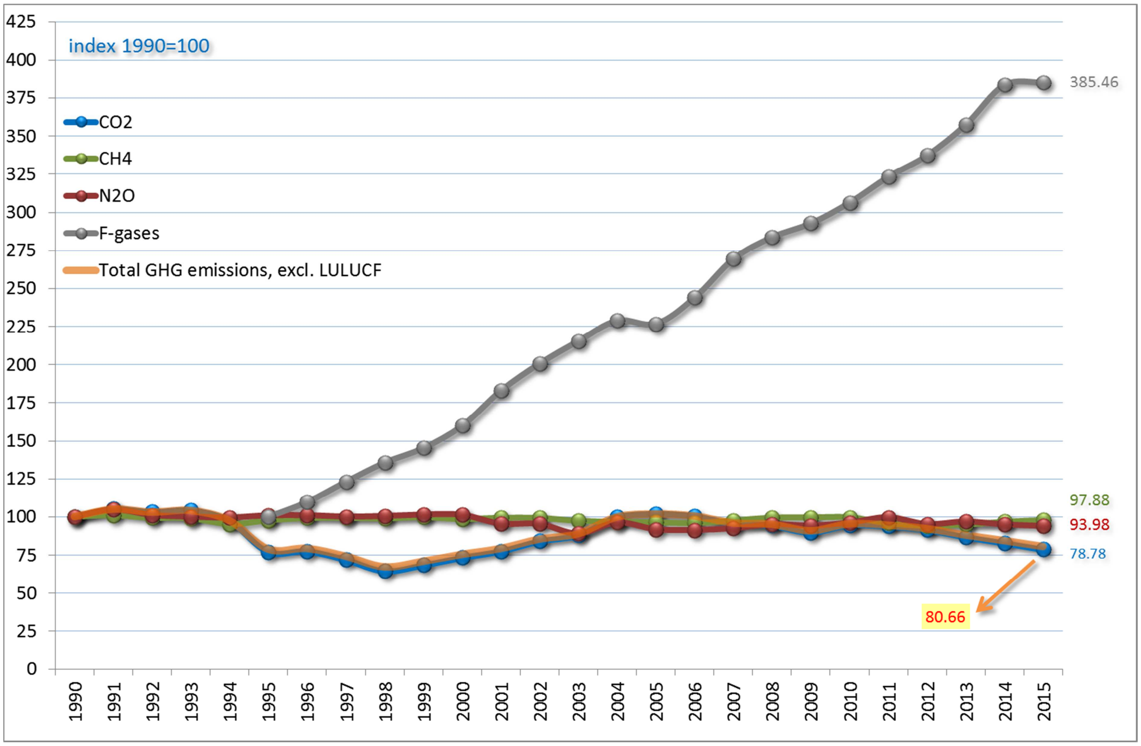
CRF Sectors



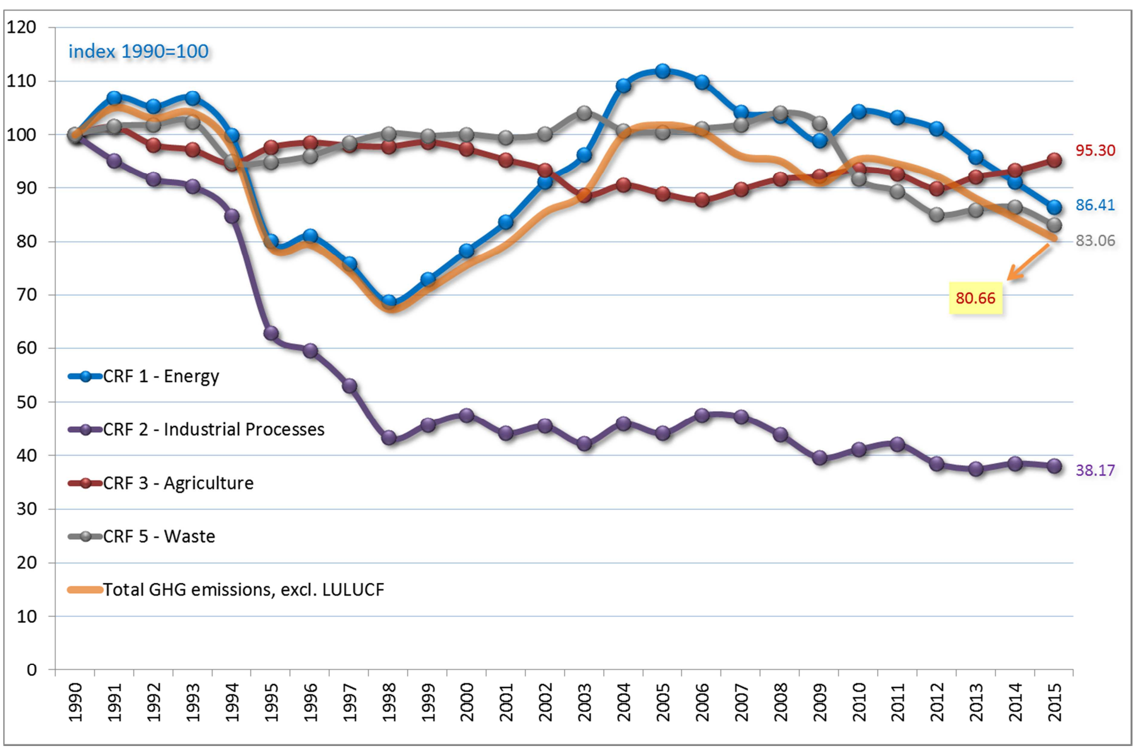
Sources: Environment Agency and MDDI-DEV.

Figure 2-28 – Luxembourg's GHG emissions (excl. LULUCF) – indexes: 1990-2015

GHG



CRF Sectors



Sources: Environment Agency and MDDI-DEV.

A good example for a **technological change** in production took place in the iron and steel industry, where the steel production process was moved from blast furnaces to electric arc furnaces between 1994 and 1998 and, therefore, solid fuels (coke) were replaced, to a very large extent, by electricity and natural gas. Due to that technological change, the total energy consumption in steel industry was significantly reduced and the "energy-mix" greatly modified. This process change was the main driver for the reduction in GHG emissions observed between 1994 and 1998. Changes also occurred in the industrial and residential/commercial/institutional sectors, where the consumption of liquid fuels (residual oil, gasoil) was reduced in favour of natural gas in conjunction with the extension of the natural gas network in Luxembourg.

The road transport sector, on the other hand, is a clear example on **how activity levels of a source category can influence the overall GHG emission trend**. Indeed, the upward trend for GHG emissions recorded from 1999 to 2004 was merely justified by increasing energy consumption and fuel sales in the transport sector. The stabilization spotted for the inventory years 2004 to 2006 was largely the result of relatively steady sales of road fuels that peaked in 2005. Finally, the decrease in total emissions from 2006 to 2007 and the period of relative stability that followed was driven by a "road fuel sales to non-residents" related emissions reduction, which reached its lower level in 2009 (financial and economic crisis), combined with a diminution of GHG emissions from the power generation sector, the latter being exceptionally important for the years 2008 and 2011-2015 when the main power plant of the country experienced maintenance or reduced activities which resulted in several months without substantial production.

More detailed explanations are provided in Sections 2.3 (dealing with gases) and 2.4 (dealing with CRF Sectors), as well as in the analysis of emission trends for each sector (see the first sections of CRF Sector Chapters 3 to 7).

A fundamental point worth mentioning when analysing Luxembourg's GHG emission trends and their composition over time, is **the small size of Luxembourg**, and therefore, the special nature of its economy. Indeed, the structure of the economy, the related energy demand and the energy and emission balances may vary significantly, whether a new economic activity starts its operations or an existing one ceases them. This characteristic explains, for instance, the reduction of emissions pertaining to the industrial sector: with 7.9 Mio. t in 1990, CO_2e emissions from industrial processes and fuel combustion in industry accounted for 62% of total GHG emissions. They could eventually be reduced to 2.09 Mio. t in 1998 – *i.e.* 26% of total GHG emissions – mainly after the reorganization of the steel industry took place in the mid-nineties (move from blast furnaces to electric arc furnaces indicated above). At that time, GHG emissions of Luxembourg were almost one third below the base year level. Another illustrative example is the building of the TWINerg power plant. This plant started its operation in mid-2002 and, by 2010, was responsible of about 0.96 Mio. t CO_2, *i.e.* around 8% of the total GHG emissions. In the last few years, the plant's activity level progressively decreased until its final shutdown in 2016.

These considerations can easily be identified in Table 2-11 and Table 2-12, and their associated figures, which assemble CRF source categories in such a way that GHG and individual gas emission sources are distributed between main emitters – such as energy production, industry, road transportation – and other categories.

2.3 Description of Emission Trends by Gas

For the different GHG, trends over the period 1990-2015 (and 2014-2015) were as follows:

- CO_2: .... -21.2% (-5.0%)
- CH_4: .... -2.1% (+1.1%)
- N_2O: ....-6.0% (-1.1%)
- F-gases: ....+8563.9% (+0.5%)

For carbon dioxide, the development between 1990 and 2015 hides a U-shape evolution over the period as well as important changes in the sources of CO_2 emissions: declining emissions in industrial combustion, increasing emissions from transport and natural gas fired power plants – as underlined in the previous section.

Methane emissions have slightly declined over the period due to the conjunction of reduced methane emissions in waste and waste water management (-25%) that surpasses growing emissions in energy use (+9.6%). Methane emissions in agriculture increased slightly (+1.60%).

Nitrous oxide emissions development is the result of declining emissions from the agriculture and various other sources such as anaesthesia, waste water handling and composting. Agricultural soils emissions dropped by 22.6% over the period 1990-2015. This decrease has more than balanced the sharp increase – +77.9% – recorded for fossil fuels related N_2O emissions from combustion activities (mainly for the road transportation and the other sectors).

Finally, with regard to F-gases, HFC emissions were about 2.8 times higher in 2015 than in the base year (1995), whereas SF_6 emissions showed a 6.4-fold increase. These evolutions can be visualized in Table 2-12, which distributes, for each GHG, emissions amongst the main source categories, as well as in the associated Figure 2-28 and Figure 2-29. These table and figures offer the opportunity to further analyse emission trends for each of the gases.

Table 2-11 – Luxembourg's GHG emissions (excl. LULUCF) –sector-based breakdown: 1990-2015

Gg (1000 t.) CO_2 equivalent	CRF Categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Main Emitting Source Categories																											
Public Electricity & Heat Production	1A1a	35.64	37.29	37.19	35.38	34.61	93.54	82.35	89.72	155.93	173.46	120.17	282.26	1029.32	1036.71	1257.41	1243.19	1305.28	1181.71	996.00	1190.78	1205.97	1004.16	1042.72	685.89	668.52	457.22
(excl. waste incineration)		NA	NA	NA	NA	NA	0.93%	0.81%	0.94%	1.79%	1.88%	1.24%	2.73%	8.68%	8.43%	9.05%	8.80%	9.31%	8.86%	7.65%	9.39%	9.08%	7.74%	8.20%	5.80%	5.88%	4.28%
Iron & Steel	1A2a + 2C1	6396.29	6090.21	5608.07	5844.00	4837.99	2781.92	2518.25	1629.12	451.44	493.16	478.70	548.43	530.66	512.64	558.40	534.25	657.05	630.55	576.48	461.98	515.71	461.10	402.43	380.64	377.78	401.29
(fuel combustion & processes)		50.36%	45.65%	42.71%	44.07%	38.94%	27.55%	24.80%	17.11%	5.18%	5.35%	4.94%	5.30%	4.48%	4.17%	4.02%	3.78%	4.69%	4.73%	4.43%	3.64%	3.88%	3.55%	3.16%	3.22%	3.32%	3.76%
Other Manufacturing Industries &	1A2b/c/d/e/f + 2A	1477.45	1552.52	1625.94	1503.03	1704.33	1541.31	1595.39	1610.36	1583.24	1769.96	1644.01	1608.68	1527.84	1430.13	1535.83	1522.45	1529.32	1453.15	1383.20	1296.03	1343.46	1377.56	1317.23	1267.72	1297.89	1232.39
Construction (fuel combustion & processes)		11.63%	11.64%	12.38%	11.33%	13.72%	15.26%	15.71%	16.92%	18.17%	19.19%	16.95%	15.53%	12.88%	11.63%	11.05%	10.78%	10.90%	10.90%	10.62%	10.21%	10.12%	10.62%	10.35%	10.71%	11.42%	11.55%
Road Transportation - national fleet	1A3b	862.85	903.28	939.50	987.54	989.70	1045.77	1071.21	1114.49	1165.17	1177.46	1225.36	1294.36	1351.97	1380.06	1422.61	1442.80	1502.04	1527.06	1600.28	1594.82	1606.10	1632.64	1632.35	1627.59	1693.69	1703.20
		6.79%	6.77%	7.16%	7.45%	7.97%	10.36%	10.55%	11.71%	13.37%	12.76%	12.64%	12.50%	11.40%	11.22%	10.23%	10.21%	10.71%	11.45%	12.28%	12.57%	12.10%	12.58%	12.83%	13.75%	14.90%	15.96%
Road Transportation - fuel export	1A3b	1692.86	2239.97	2479.70	2481.06	2535.18	2244.16	2325.65	2543.01	2670.22	2980.76	3566.95	3741.18	3873.86	4397.94	5315.39	5679.26	5305.42	5001.22	5035.17	4518.41	4865.64	5226.24	4910.05	4778.73	4412.53	3980.90
		13.33%	16.79%	18.89%	18.71%	20.41%	22.22%	22.91%	26.71%	30.64%	32.31%	36.78%	36.12%	32.67%	35.76%	38.24%	40.20%	37.83%	37.51%	38.65%	35.61%	36.65%	40.28%	38.59%	40.38%	38.81%	37.30%
Residential Fuel Combustion	1A4b	678.85	813.59	747.72	741.78	706.14	716.08	785.96	761.62	792.10	711.22	1077.55	1169.82	1113.50	1156.69	1237.43	1211.99	1199.93	1160.15	1193.15	1179.67	1158.09	1061.32	1079.92	1072.61	970.61	1067.06
		5.34%	6.10%	5.69%	5.59%	5.68%	7.09%	7.74%	8.00%	9.09%	7.71%	11.11%	11.29%	9.39%	9.41%	8.90%	8.58%	8.56%	8.70%	9.16%	9.30%	8.72%	8.18%	8.49%	9.06%	8.54%	10.00%
Commercial & Institutional Fuel	1A4a	640.16	770.15	710.60	702.46	676.83	682.30	761.54	738.29	772.36	692.13	548.23	498.40	500.43	497.13	462.90	418.25	395.34	348.55	376.96	380.45	498.51	332.51	439.55	464.17	388.76	475.67
Combustion		5.04%	5.77%	5.41%	5.30%	5.45%	6.76%	7.50%	7.76%	8.86%	7.50%	5.65%	4.81%	4.22%	4.04%	3.33%	2.96%	2.82%	2.61%	2.89%	3.00%	3.75%	2.56%	3.45%	3.92%	3.42%	4.46%
Agriculture (fuel combustion,	1A4c+4	751.06	762.39	736.90	727.91	712.37	732.06	740.02	737.77	737.06	760.30	722.95	705.61	693.30	659.84	674.84	662.83	654.74	668.37	684.51	688.12	697.49	689.85	670.49	682.20	691.12	706.03
livestock, crops, soils)		5.91%	5.72%	5.61%	5.49%	5.73%	7.25%	7.29%	7.75%	8.46%	8.24%	7.45%	6.81%	5.85%	5.37%	4.85%	4.69%	4.67%	5.01%	5.25%	5.42%	5.25%	5.32%	5.27%	5.77%	6.08%	6.61%
Other Source Categories																											
Municipal Waste Incineration	1A1a (5C)	35.64	37.29	37.19	35.38	34.61	93.54	82.35	89.72	155.93	173.46	120.17	282.26	1029.32	1036.71	1257.41	1243.19	1305.28	1181.71	996.00	1190.78	1205.97	1004.16	1042.72	685.89	668.52	457.22
(with energy & heat recovery)		0.28%	0.28%	0.28%	0.27%	0.28%	0.93%	0.81%	0.94%	1.79%	1.88%	1.24%	2.73%	8.68%	8.43%	9.05%	8.80%	9.31%	8.86%	7.65%	9.39%	9.08%	7.74%	8.20%	5.80%	5.88%	4.28%
Other Transport	1A3a/c/d	28.96	29.20	29.27	29.47	28.71	23.52	26.09	25.74	25.60	25.76	25.32	27.29	24.44	21.74	17.53	11.96	9.24	12.07	13.68	12.94	13.88	13.76	12.57	10.84	12.15	8.73
		0.23%	0.22%	0.22%	0.22%	0.23%	0.23%	0.26%	0.27%	0.29%	0.28%	0.26%	0.26%	0.21%	0.18%	0.13%	0.08%	0.07%	0.09%	0.10%	0.10%	0.10%	0.11%	0.10%	0.09%	0.11%	0.08%
Other Energy Sources	1A5 + 1B2b	3.10	3.10	26.65	23.50	21.92	10.71	18.42	22.91	33.92	62.73	12.17	24.16	13.49	3.25	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
(incl. lubricants reported under 1A3b)		0.02%	0.02%	0.20%	0.18%	0.18%	0.11%	0.18%	0.24%	0.39%	0.68%	0.13%	0.23%	0.11%	0.03%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
F-gases	2F	0.00	0.00	13.68	14.70	15.98	18.31	20.06	22.54	24.98	26.78	29.58	33.49	36.38	38.70	40.78	39.79	42.77	47.37	49.77	51.16	53.46	56.34	58.73	59.80	65.42	65.05
		0.00%	0.00%	0.10%	0.11%	0.13%	0.18%	0.20%	0.24%	0.29%	0.29%	0.30%	0.32%	0.31%	0.31%	0.29%	0.28%	0.31%	0.36%	0.38%	0.40%	0.40%	0.43%	0.46%	0.51%	0.58%	0.61%
Municipal Waste Disposal on Land	5A	3.10	3.10	26.65	23.50	21.92	10.71	18.42	22.91	33.92	62.73	12.17	24.16	13.49	3.25	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
		0.02%	0.02%	0.20%	0.18%	0.18%	0.11%	0.18%	0.24%	0.39%	0.68%	0.13%	0.23%	0.11%	0.03%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Waste Water Handling	5B	0.00	0.00	13.68	14.70	15.98	18.31	20.06	22.54	24.98	26.78	29.58	33.49	36.38	38.70	40.78	39.79	42.77	47.37	49.77	51.16	53.46	56.34	58.73	59.80	65.42	65.05
		0.00%	0.00%	0.10%	0.11%	0.13%	0.18%	0.20%	0.24%	0.29%	0.29%	0.30%	0.32%	0.31%	0.31%	0.29%	0.28%	0.31%	0.36%	0.38%	0.40%	0.40%	0.43%	0.46%	0.51%	0.58%	0.61%
Composting	5D	95.76	97.54	97.56	95.90	86.95	86.45	86.45	88.58	88.76	88.82	84.76	83.72	83.53	83.86	78.96	76.26	74.63	73.85	72.19	71.12	59.47	59.16	56.02	56.89	56.02	53.17
		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total GHG excluding LULUCF		12701.75	13339.64	13130.30	13260.30	12423.23	10098.68	10152.23	9519.32	8715.60	9225.52	9697.65	10357.34	11857.93	12297.33	13900.52	14126.27	14024.07	13333.36	13027.41	12687.65	13277.45	12975.39	12723.76	11833.01	11368.66	10673.21
		100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Memo Items																											
International Bunkers - Aviation		407.04	425.44	411.32	406.79	516.04	584.97	635.63	760.42	921.82	1040.09	991.33	1072.20	1161.66	1210.17	1316.77	1337.97	1252.16	1345.90	1354.79	1297.93	1327.05	1246.22	1149.85	1155.61	1254.37	1414.01
		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
International Bunkers - Marine		0.09	0.09	0.09	0.12	0.10	0.10	0.10	0.09	0.09	0.10	0.11	0.11	0.12	0.12	0.12	0.16	0.17	0.13	0.15	0.12	0.11	0.14	0.13	0.11	0.12	0.12
		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CO_2 Emissions from Biomass		159.05	163.07	163.73	159.33	157.46	153.78	135.56	146.84	139.67	148.82	150.04	164.85	166.20	182.13	195.94	294.24	297.72	440.04	452.89	425.22	443.38	451.16	446.49	475.26	558.97	613.56
		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Sources: Environment Agency and MDDI-DEV.

Notes: (1) These percentages are relative to the total GHG emissions, excluding LULUCF.

(2) The methane emissions are converted in CO_2 equivalents by multiplying the emissions by 25, *i.e.* the global warming potential (GWP) value for methane based on the effects of GHG over a 100-year time horizon.

(3) The nitrous oxide emissions are converted in CO_2 equivalents by multiplying the emissions by 298, *i.e.* the global warming potential (GWP) value for nitrous oxide based on the effects of GHG over a 100-year time horizon.

(4) The F-gases are those not covered by the Montreal Protocol, *i.e.* the HFCs, PFCs and SF_6 expressed in CO_2 equivalents using the global warming potential (GWP) values based on the effects of GHG over a 100-year time horizon.

Table 2-12 – Luxembourg's GHG emissions and removals – details by main gases: 1990-2015

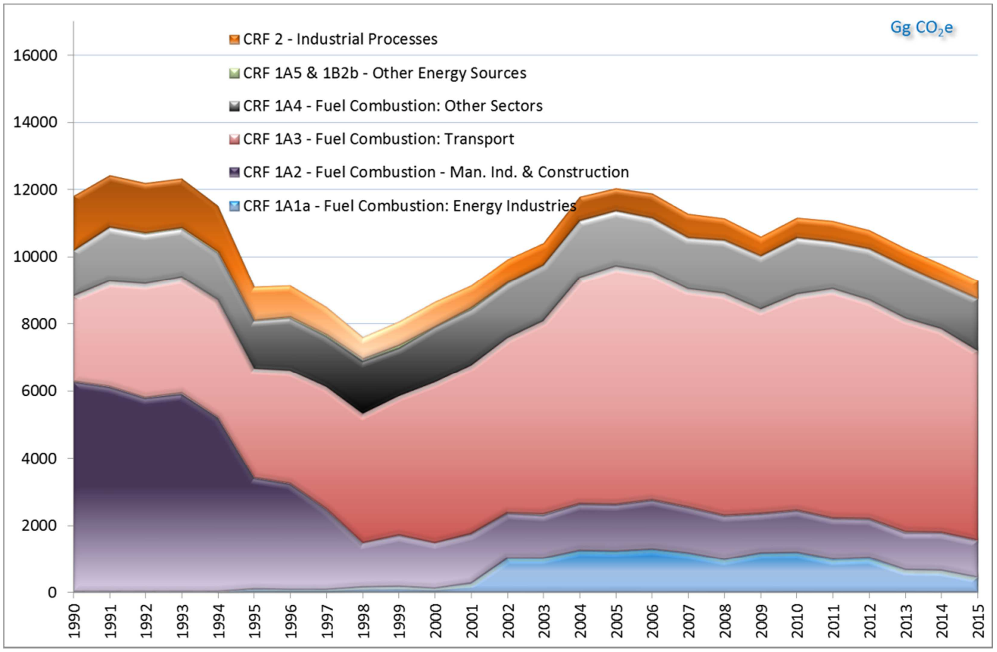
Gg (1000 t.) CO_2 equivalent	1990 (base year)	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
CO_2	**11812.05**	**12428.21**	**12188.83**	**12327.93**	**11516.20**	**9124.44**	**9171.13**	**8523.01**	**7639.44**	**8090.96**	**8673.16**	**9166.12**	**9942.38**	**10411.66**	**11785.51**	**12044.64**	**11882.64**	**11290.95**	**11155.91**	**10616.84**	**11184.97**	**11088.43**	**10816.35**	**10266.72**	**9797.16**	**9305.96**
	92.79%	*92.98%*	*92.90%*	*93.00%*	*92.72%*	*90.79%*	*90.73%*	*90.08%*	*89.05%*	*89.50%*	*90.19%*	*90.73%*	*91.37%*	*91.94%*	*92.67%*	*92.93%*	*92.85%*	*92.36%*	*92.11%*	*91.74%*	*92.06%*	*92.08%*	*92.06%*	*91.56%*	*91.09%*	*90.62%*
of which																										
CRF 1 - Energy	10181.27	10875.67	10707.30	10869.56	10150.20	8118.88	8221.78	7682.75	6958.78	7373.83	7929.34	8479.49	9237.78	9762.66	11079.05	11364.51	11152.78	10570.25	10493.11	10024.18	10569.54	10458.81	10248.47	9717.73	9237.41	8753.47
	79.98%	*81.36%*	*81.61%*	*82.00%*	*81.73%*	*80.79%*	*81.34%*	*81.20%*	*81.12%*	*81.57%*	*82.45%*	*83.93%*	*84.89%*	*86.21%*	*87.12%*	*87.68%*	*87.14%*	*86.46%*	*86.64%*	*86.61%*	*86.99%*	*86.85%*	*87.22%*	*86.66%*	*85.88%*	*85.24%*
CRF 1A1 - Fuel Combustion from	33.29	34.83	34.73	33.04	32.32	91.29	80.61	87.66	153.38	170.54	117.37	279.33	1025.62	1032.90	1253.26	1239.18	1301.09	1177.54	991.94	1186.67	1202.05	1000.20	1038.72	682.30	664.65	453.05
Energy Industries	*0.26%*	*0.26%*	*0.26%*	*0.25%*	*0.26%*	*0.91%*	*0.80%*	*0.93%*	*1.79%*	*1.89%*	*1.22%*	*2.76%*	*9.43%*	*9.12%*	*9.85%*	*9.56%*	*10.17%*	*9.63%*	*8.19%*	*10.25%*	*9.89%*	*8.31%*	*8.84%*	*6.08%*	*6.18%*	*4.41%*
CRF 1A2 - Fuel Combustion from	6249.95	6096.36	5757.50	5892.13	5179.38	3324.81	3171.10	2406.43	1361.75	1550.71	1382.99	1474.29	1359.69	1297.60	1393.61	1384.22	1461.69	1368.79	1310.70	1180.01	1259.38	1230.86	1174.96	1126.32	1138.33	1105.38
Manuf. Industries & Construction	*49.09%*	*45.61%*	*43.88%*	*44.45%*	*41.70%*	*33.08%*	*31.37%*	*25.43%*	*15.87%*	*17.15%*	*14.38%*	*14.59%*	*12.50%*	*11.46%*	*10.96%*	*10.68%*	*11.42%*	*11.20%*	*10.82%*	*10.20%*	*10.37%*	*10.22%*	*10.00%*	*10.04%*	*10.58%*	*10.76%*
CRF 1A3 - Fuel Combustion from	2556.05	3138.61	3411.45	3460.08	3513.75	3275.79	3384.73	3644.81	3823.62	4146.70	4779.47	5025.60	5214.90	5764.62	6720.41	7099.29	6782.31	6502.22	6605.85	6083.26	6437.63	6818.83	6501.85	6363.40	6065.44	5642.56
Transport	*20.08%*	*23.48%*	*26.00%*	*26.10%*	*28.29%*	*32.60%*	*33.48%*	*38.52%*	*44.57%*	*45.87%*	*49.70%*	*49.74%*	*47.92%*	*50.90%*	*52.85%*	*54.77%*	*52.99%*	*53.19%*	*54.54%*	*52.56%*	*52.98%*	*56.62%*	*55.34%*	*56.75%*	*56.39%*	*54.95%*
of which, "road fuel export" (1)	1692.86	2239.97	2479.70	2481.06	2535.18	2244.16	2325.65	2543.01	2670.22	2980.76	3566.95	3741.18	3873.86	4397.94	5315.39	5679.26	5305.42	5001.22	5035.17	4518.41	4865.64	5226.24	4910.05	4778.73	4412.53	3980.90
	13.30%	*16.76%*	*18.90%*	*18.72%*	*20.41%*	*22.33%*	*23.01%*	*26.88%*	*31.13%*	*32.97%*	*37.09%*	*37.03%*	*35.60%*	*38.84%*	*41.80%*	*43.82%*	*41.45%*	*40.91%*	*41.57%*	*39.04%*	*40.05%*	*43.40%*	*41.79%*	*42.62%*	*41.02%*	*38.77%*
CRF 1A4 - Fuel Combustion from	1338.86	1602.75	1476.95	1460.78	1402.79	1416.24	1566.89	1520.90	1586.07	1443.10	1637.31	1676.06	1624.02	1664.22	1711.59	1641.64	1607.50	1521.52	1584.44	1574.05	1670.29	1408.74	1532.76	1545.54	1368.82	1552.32
Other Sectors	*10.52%*	*11.99%*	*11.26%*	*11.02%*	*11.29%*	*14.09%*	*15.50%*	*16.08%*	*18.49%*	*15.96%*	*17.03%*	*16.59%*	*14.92%*	*14.70%*	*13.46%*	*12.67%*	*12.56%*	*12.45%*	*13.08%*	*13.60%*	*13.75%*	*11.70%*	*13.04%*	*13.78%*	*12.73%*	*15.12%*
CRF 1A5 & 1B2b - Other Energy	3.10	3.10	26.65	23.50	21.92	10.71	18.42	22.91	33.92	62.73	12.17	24.16	13.49	3.25	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Sources	*0.02%*	*0.02%*	*0.20%*	*0.18%*	*0.18%*	*0.11%*	*0.18%*	*0.24%*	*0.40%*	*0.69%*	*0.13%*	*0.24%*	*0.12%*	*0.03%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
CRF 2 - Industrial Processes	1630.19	1551.83	1480.69	1457.42	1364.63	1004.43	948.36	838.80	678.64	716.01	741.93	684.34	701.69	646.19	704.04	676.23	726.81	717.62	659.95	588.59	611.24	624.73	562.82	543.19	553.94	546.69
	12.81%	*11.61%*	*11.29%*	*10.99%*	*10.99%*	*9.99%*	*9.38%*	*8.87%*	*7.91%*	*7.92%*	*7.71%*	*6.77%*	*6.45%*	*5.71%*	*5.54%*	*5.22%*	*5.68%*	*5.87%*	*5.45%*	*5.09%*	*5.03%*	*5.19%*	*4.79%*	*4.84%*	*5.15%*	*5.32%*
Other Sources (2)	21.83	21.32	20.25	19.20	18.45	19.94	19.64	18.73	17.65	16.97	16.15	16.46	17.97	15.59	18.22	19.51	17.94	18.17	24.63	22.84	24.06	28.93	29.28	32.43	28.49	29.35
	0.17%	*0.16%*	*0.15%*	*0.14%*	*0.15%*	*0.20%*	*0.19%*	*0.20%*	*0.21%*	*0.19%*	*0.17%*	*0.16%*	*0.17%*	*0.14%*	*0.14%*	*0.15%*	*0.14%*	*0.15%*	*0.20%*	*0.20%*	*0.20%*	*0.24%*	*0.25%*	*0.29%*	*0.26%*	*0.29%*
CH_4 (3)	**634.97**	**641.56**	**630.76**	**629.56**	**605.20**	**620.68**	**630.29**	**631.08**	**628.50**	**633.85**	**626.10**	**630.97**	**630.42**	**618.77**	**614.43**	**612.34**	**609.15**	**620.07**	**631.34**	**632.38**	**633.18**	**608.81**	**598.19**	**602.96**	**614.86**	**621.50**
	4.99%	*4.80%*	*4.81%*	*4.75%*	*4.87%*	*6.18%*	*6.24%*	*6.67%*	*7.33%*	*7.01%*	*6.51%*	*6.25%*	*5.79%*	*5.46%*	*4.83%*	*4.72%*	*4.76%*	*5.07%*	*5.21%*	*5.46%*	*5.21%*	*5.06%*	*5.09%*	*5.38%*	*5.72%*	*6.05%*
of which																										
CRF 1 - Energy	45.90	48.63	47.80	47.22	45.43	46.16	47.65	47.34	46.67	47.19	47.72	51.50	65.02	65.36	71.16	70.05	72.15	67.35	65.27	65.69	69.86	60.53	62.81	56.05	54.08	50.29
	0.36%	*0.36%*	*0.36%*	*0.36%*	*0.37%*	*0.46%*	*0.47%*	*0.50%*	*0.54%*	*0.52%*	*0.50%*	*0.51%*	*0.60%*	*0.58%*	*0.56%*	*0.54%*	*0.56%*	*0.55%*	*0.54%*	*0.57%*	*0.57%*	*0.50%*	*0.53%*	*0.50%*	*0.50%*	*0.49%*
CRF 3A+3B - Enteric Fermentation and	486.01	488.26	478.21	478.13	464.32	479.39	486.53	485.38	482.56	487.92	481.27	483.23	468.18	453.36	447.62	447.71	442.53	458.02	469.84	471.78	479.83	466.18	455.58	466.39	480.21	493.80
Manure Management	*3.82%*	*3.65%*	*3.64%*	*3.61%*	*3.74%*	*4.77%*	*4.81%*	*5.13%*	*5.63%*	*5.40%*	*5.00%*	*4.78%*	*4.30%*	*4.00%*	*3.52%*	*3.45%*	*3.46%*	*3.75%*	*3.88%*	*4.08%*	*3.95%*	*3.87%*	*3.88%*	*4.16%*	*4.46%*	*4.81%*
Other Sources (4)	103.07	104.66	104.75	104.21	95.45	95.14	96.11	98.37	99.27	98.74	97.11	96.24	97.21	100.04	95.65	94.58	94.47	94.70	96.23	94.92	83.49	82.11	79.80	80.52	80.56	77.41
	0.81%	*0.78%*	*0.80%*	*0.79%*	*0.77%*	*0.95%*	*0.95%*	*1.04%*	*1.16%*	*1.09%*	*1.01%*	*0.95%*	*0.89%*	*0.88%*	*0.75%*	*0.73%*	*0.74%*	*0.77%*	*0.79%*	*0.82%*	*0.69%*	*0.68%*	*0.68%*	*0.72%*	*0.75%*	*0.75%*
N_2O (5)	**282.56**	**295.94**	**285.82**	**282.57**	**281.17**	**285.11**	**285.31**	**282.91**	**283.90**	**286.56**	**286.21**	**269.79**	**269.45**	**251.46**	**272.16**	**259.54**	**258.21**	**261.26**	**268.70**	**266.50**	**271.49**	**281.56**	**268.89**	**273.54**	**268.39**	**265.56**
	2.22%	*2.21%*	*2.18%*	*2.13%*	*2.26%*	*2.84%*	*2.82%*	*2.99%*	*3.31%*	*3.17%*	*2.98%*	*2.67%*	*2.48%*	*2.22%*	*2.14%*	*2.00%*	*2.02%*	*2.14%*	*2.22%*	*2.30%*	*2.23%*	*2.34%*	*2.29%*	*2.44%*	*2.50%*	*2.59%*
of which																										
CRF 1 - Energy	36.71	42.13	46.01	48.76	51.67	49.15	50.10	50.58	50.05	51.58	53.20	53.48	52.72	52.30	52.94	52.86	52.92	56.38	60.15	59.02	64.19	68.92	67.98	68.48	68.17	65.30
	0.29%	*0.32%*	*0.35%*	*0.37%*	*0.42%*	*0.49%*	*0.50%*	*0.53%*	*0.58%*	*0.57%*	*0.55%*	*0.53%*	*0.48%*	*0.46%*	*0.42%*	*0.41%*	*0.41%*	*0.46%*	*0.50%*	*0.51%*	*0.53%*	*0.57%*	*0.58%*	*0.61%*	*0.63%*	*0.64%*
CRF 3D - Agricultural Soils	188.73	197.58	184.66	177.97	174.29	178.38	177.15	174.34	175.38	176.99	174.58	158.39	160.63	142.04	162.69	149.87	148.37	146.41	147.99	148.53	149.36	157.25	148.95	151.98	145.76	146.15
	1.48%	*1.48%*	*1.41%*	*1.34%*	*1.40%*	*1.77%*	*1.75%*	*1.84%*	*2.04%*	*1.96%*	*1.82%*	*1.57%*	*1.48%*	*1.25%*	*1.28%*	*1.16%*	*1.16%*	*1.20%*	*1.22%*	*1.28%*	*1.23%*	*1.31%*	*1.27%*	*1.36%*	*1.36%*	*1.42%*
Other Sources (6)	57.13	56.23	55.15	55.84	55.21	57.58	58.06	57.98	58.46	58.00	58.42	57.92	56.10	57.12	56.53	56.81	56.92	58.47	60.56	58.95	57.94	55.39	51.96	53.09	54.46	54.11
	0.45%	*0.42%*	*0.42%*	*0.42%*	*0.44%*	*0.57%*	*0.57%*	*0.61%*	*0.68%*	*0.64%*	*0.61%*	*0.57%*	*0.52%*	*0.50%*	*0.44%*	*0.44%*	*0.44%*	*0.48%*	*0.50%*	*0.51%*	*0.48%*	*0.46%*	*0.44%*	*0.47%*	*0.51%*	*0.53%*
F-gases (7)	**0.88**	**0.98**	**14.76**	**15.88**	**17.28**	**19.70**	**21.62**	**24.24**	**26.72**	**28.61**	**31.50**	**36.04**	**39.53**	**42.43**	**45.06**	**44.65**	**48.04**	**53.06**	**55.87**	**57.66**	**60.33**	**63.65**	**66.41**	**70.41**	**75.56**	**75.92**
	0.01%	*0.01%*	*0.11%*	*0.12%*	*0.14%*	*0.20%*	*0.21%*	*0.26%*	*0.31%*	*0.32%*	*0.33%*	*0.36%*	*0.36%*	*0.37%*	*0.35%*	*0.34%*	*0.38%*	*0.43%*	*0.46%*	*0.50%*	*0.50%*	*0.53%*	*0.57%*	*0.63%*	*0.70%*	*0.74%*
Total GHG excluding LULUCF	**12730.46**	**13366.69**	**13120.17**	**13255.94**	**12419.85**	**10049.92**	**10108.35**	**9461.25**	**8578.56**	**9039.99**	**9616.97**	**10102.92**	**10881.78**	**11324.32**	**12717.16**	**12961.17**	**12798.04**	**12225.34**	**12111.83**	**11573.37**	**12149.97**	**12042.45**	**11749.85**	**11213.64**	**10755.97**	**10268.93**
	100.00%	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*
LULUCF	**48.33**	**-228.91**	**-558.08**	**-653.15**	**-463.96**	**-567.04**	**-607.46**	**-690.19**	**-574.62**	**-672.33**	**-702.01**	**-713.71**	**-715.10**	**-677.74**	**-681.49**	**-635.91**	**-553.84**	**-473.93**	**-490.62**	**-467.90**	**-152.85**	**-274.89**	**-360.60**	**-535.93**	**-456.25**	**-404.94**

Sources: Environment Agency and MDDI-DEV.

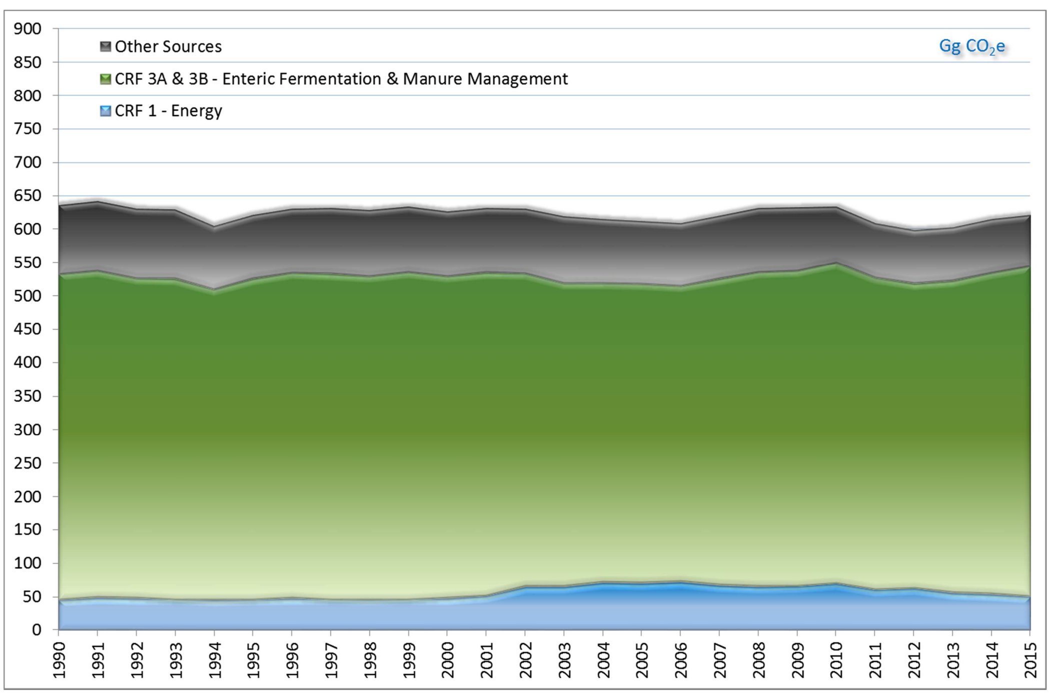
Notes: (1) The methane emissions are converted in CO_2 equivalents by multiplying the emissions by 25, *i.e.* the global warming potential (GWP) value for methane based on the effects of GHG over a 100-year time horizon.
(2) The nitrous oxide emissions are converted in CO_2 equivalents by multiplying the emissions by 298, *i.e.* the global warming potential (GWP) value for nitrous oxide based on the effects of GHG over a 100-year time horizon.
(3) The F-gases are those not covered by the Montreal Protocol, *i.e.* the HFCs, PFCs and SF_6 expressed in CO_2 equivalents using the global warming potential (GWP) values based on the effects of GHG over a 100-year time horizon.
(4) CRF 1A4a&b: there are breaks in time series between 1999 & 2000: the two CRF 1A4 sub-categories had a very similar level because national energy statistics does not allow for distinguishing these two sub-categories before 2000. Hence, a 50-50 distribution was carried out in the inventories.

Figure 2-29 – Luxembourg's GHG emissions (excl. F-gases & LULUCF) – details by main gases: 1990-2015

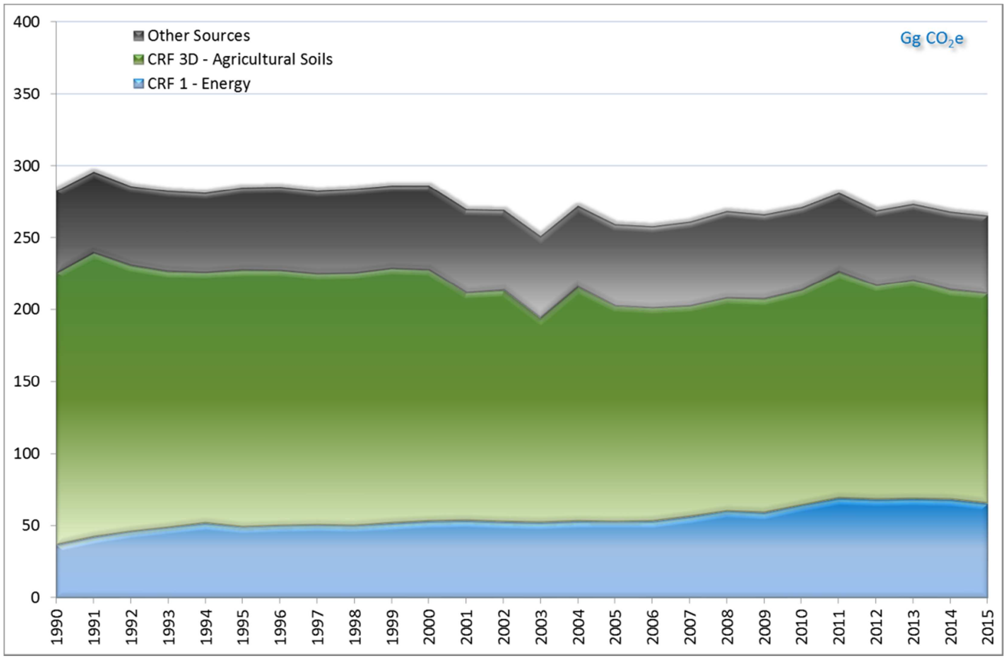
CO_2



CH_4



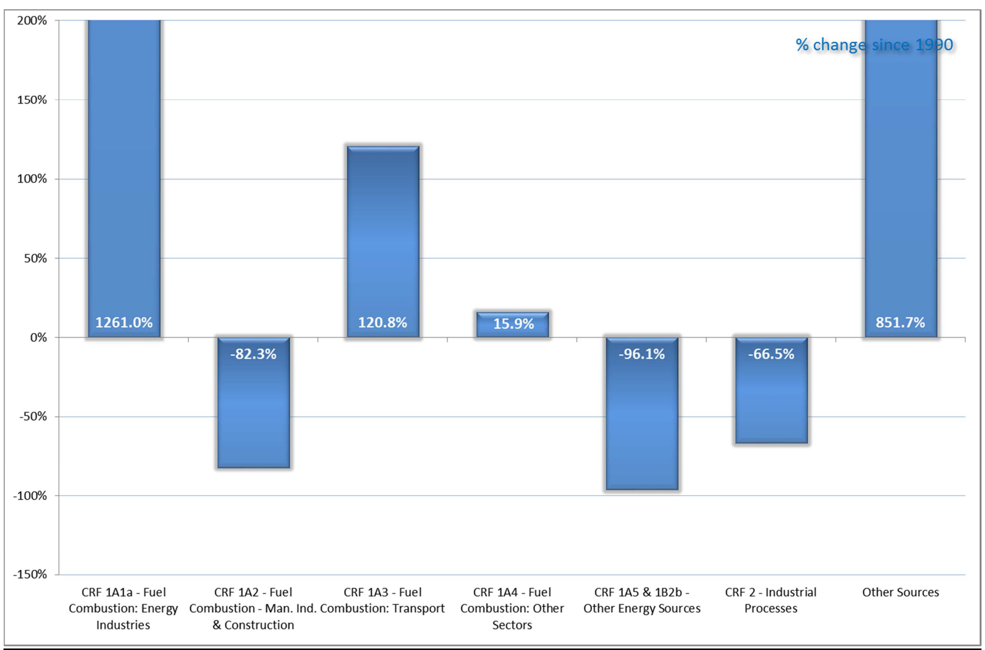
N_2O



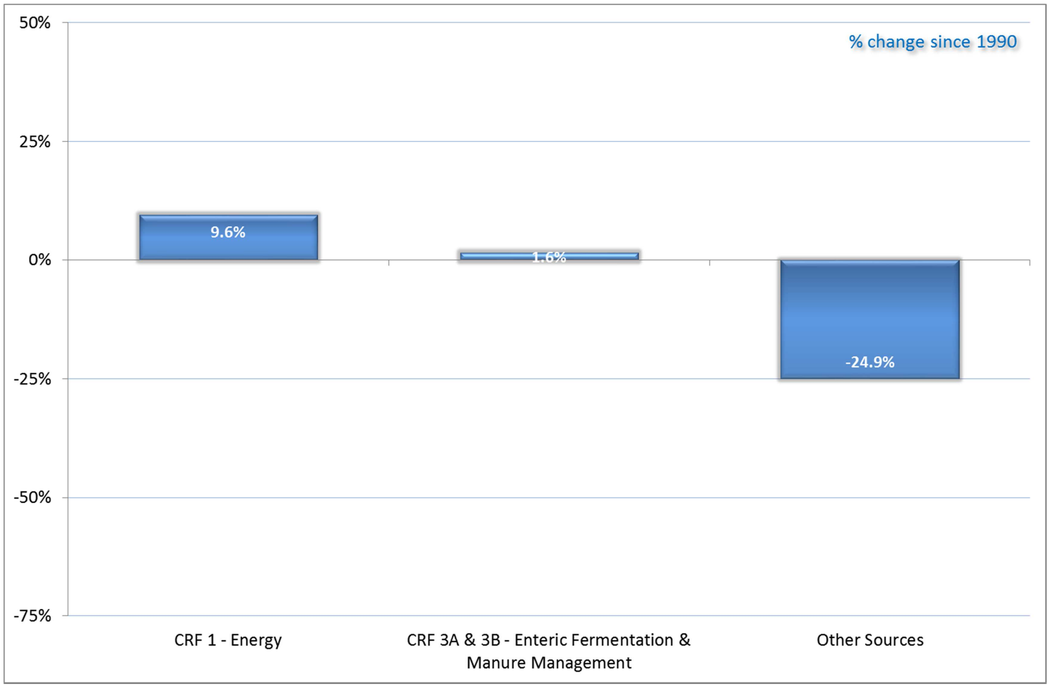
Sources: Environment Agency and MDDI-DEV.

Figure 2-30 – Luxembourg's GHG emission trends in % (excl. LULUCF) – details by main gases: 1990-2015

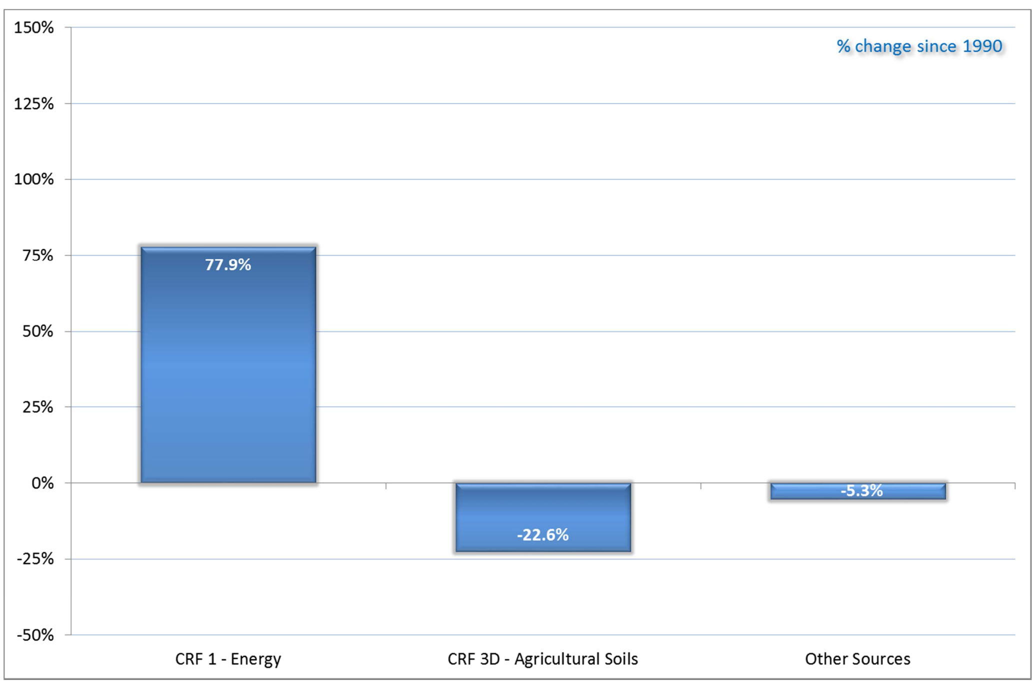
CO_2



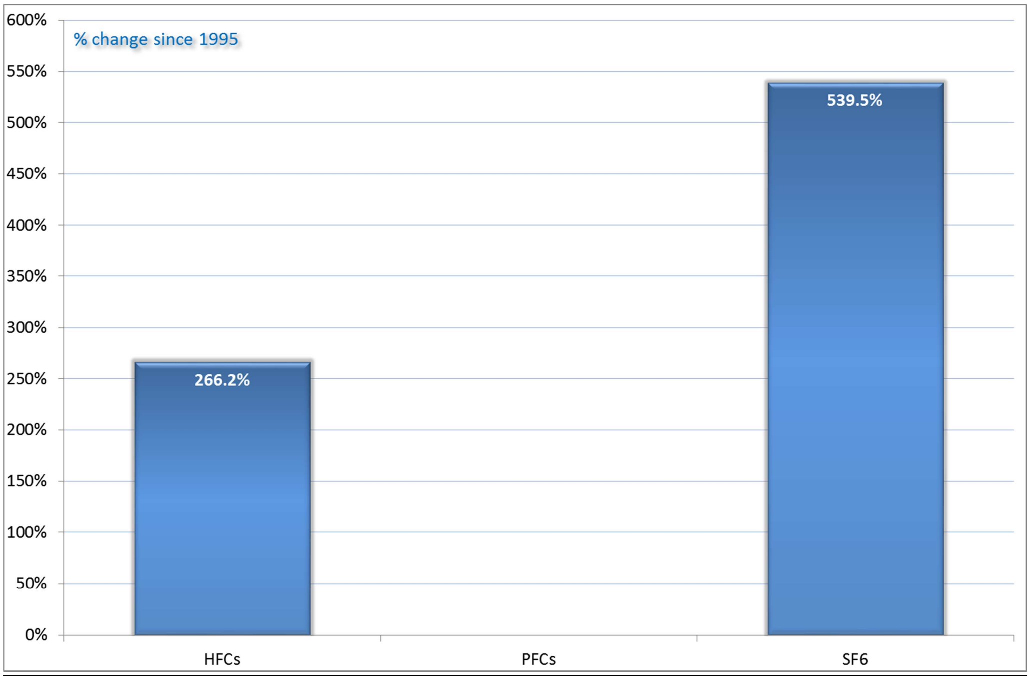
CH_4


% change since 1990
50%
25%
0%
-25%
-50%
-75%
9.6%
1.6%
-24.9%
CRF 1 - Energy
CRF 3A & 3B - Enteric Fermentation & Manure Management
Other Sources

N_2O


% change since 1990
150%
125%
100%
75%
50%
25%
0%
-25%
-50%
77.9%
-22.6%
-5.3%
CRF 1 - Energy
CRF 3D - Agricultural Soils
Other Sources

F-gases



Sources: Environment Agency and MDDI-DEV.

2.3.1 Carbon dioxide – CO_2

CRF (sub-) categories covered	1 (1A1, 1A2, 1A3, 1A4, 1A5, 1B2b), 2	
Share in total GHG emissions, excl. LULUCF	***1990***	92.8% = 11 812.05 Gg CO_2e
	2015	90.6% = 9 305.96 Gg CO_2e

Throughout the period 1990-2015, the main GHG has remained carbon dioxide, which accounted between 89.0% and 93.0% of the total GHG emissions. However, the structure of CO_2 emissions has evolved with an increase in fuel combustion, which accounted for 80.0% of total GHG emissions for the base year (1990) and climbed up to 86.24% in 2015, after having reached a maximum of 87.7 % in 2005.

Road transport, and more precisely "road fuel sales to non-residents", is, with **electricity production**, one of the culprits for this development. Indeed, in 1990, fuel combustion from the transport sector accounted for 20.08% of total GHG emissions. Then, with 5.64 Mio. t CO_2, this percentage reached 54.9% in 2015.[65] CO_2 emissions due solely to "road fuel sales to non-residents" amounted to about 1.7 Mio. t in 1990 and reached 4.0 Mio. t in 2015,[66] *i.e.* roughly a threefold increase (the same comparison shows only a twofold increase for road fuel consumed by the

65 The highest amount of emissions was recorded for the year 2005: 7.10 Mio. t CO_2 but "only" 54.8% of total GHG emissions. In fact, percentages are somewhat over-estimated in 2015 compared to the latest years for two reasons: (1) lower than "usual" emissions in electricity and heat production (CRF 1A1a) due to very low production for the TWINerg power plant for some months and (2) rather lower – compared to the previous years – emissions in the other sectors (CRF 1A4).

66 5.68 Mio. t in 2005.

national vehicle fleet). In 2015, "road fuel sales to non-residents" represented 70.5% of CO_2 emissions of the transport sector and 38.8% of the total CO_2 emissions.[67] In 1990, these percentages were 67.5% and 14%, respectively.

Another important source of CO_2 in Luxembourg is **industrial processes**, mainly carbon oxidizing of pig iron from steel industry (basic oxygen furnace steel production) and decarbonisation of mineral input in clinker and glass industry. The steel production process change described above was the main driver behind declining emissions for this sector.

2.3.2 Methane – CH_4

CRF (sub-) categories covered	1, 3A, 3B, 5A, 5B, 5D		
Share in total GHG emissions, excl. LULUCF	***1990***	4.99% =	634.97 Gg CO_2e
	2015	6.05% =	621.50 Gg CO_2e

Methane emissions originate above all from the agricultural sector, and more precisely from **enteric fermentation** and from **manure production and management**: around 75.9% of methane emissions over the period 1990-2015. As these emissions have been rather stable, total methane emissions have not varied very much.

For the other methane emitting source categories, there is a decline in **waste and waste water management** related emissions (-25%) and growing emissions in **energy use** (+9.55%). The decrease noted for waste is the result of reduced methane emissions from waste landfill sites. The increase observed for energy is mainly due to fugitive emissions from natural gas distribution and use.

2.3.3 Nitrous oxide – N_2O

CRF (sub-) categories covered	1, 2G, 3B, 3D, 5B and 5D		
Share in total GHG emissions, excl. LULUCF	***1990***	2.38% =	303.89 Gg CO_2e
	2015	2.8% =	278.98 Gg CO_2e

A large part of nitrous oxide emissions is caused by **agricultural soils** that drive the -22.56% decline observed for this gas over the period 1990-2015. Another important source, generating increasing N_2O emissions since 1990, is **road transportation**, where incomplete NO_X reduction in catalytic converters of diesel oil motor vehicles leads to N_2O emissions that were almost multiplied by a factor 3 over the period, following the increasing share of diesel vehicles on the roads. The drop in emissions observed for the **other sources** is principally the result of diminishing nitrous oxide emissions from manure management.

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[67] For 2005, these percentages were respectively 80.0% and 47.1%.

2.3.4 Hydrofluorocarbons – HFCs, perfluorocarbons - PFCs and sulphur hexafluoride – SF_6

CRF (sub-) categories covered	2D, 2F, 2G		
Share in total GHG emissions, excl. LULUCF	***1990***	0.01% =	0.88 Gg CO_2e
	2015	0.74% =	75.92 Gg CO_2e

The increase in **HFCs** emissions between 1990 and 2015 is explained by a more wide spread use of mobile and stationary cooling equipments as well as of aerosols.

No use of **PFCs** is reported.

SF_6 emissions increased from 1990 onwards following a raising use of high voltage electrical devices and a higher amount of gas emitted from noise reduction windows.

2.4 Description of Emission Trends by Category

In 2015, the energy sector accounted for almost 86.3% of the total GHG emissions, excluding LULUCF. Two sectors represent between 6.1% and 6.63% of the total emissions, excluding LULUCF: industrial processes (6.10%) and agriculture (6.63%). The remaining sector[68] (waste[69] (0.91%) was not even reaching 1% of the total GHG emitted in Luxembourg: see Table 2-10 and Figure 2-27 and Figure 2-28.

For the different sectors, trends over the period 1990-2015 (and 2014-2015) were as follows:

- Energy: ....-13.6% (-5.2%)
- Industrial Processes: ....-61.8% (-8.5%)
- Agriculture: ....-4.7% (+0.7%)
- LULUCF:..-917.21% (-14.51%)
- Waste: ....-16.9% (+12.6%)

2.4.1 CRF 1 – Energy

GHG covered	CO_2, CH_4 & N_2O	
Share in total GHG emissions, excl. LULUCF	***1990***	79.98% = 10 181.27 Gg CO_2e
	2015	85.24% = 8 753.47 Gg CO_2e

68 The sector "Others" is not reported for Luxembourg.

69 The waste sector covers only landfilled waste, wastewater handling and composting activities. Waste incineration, which is the main treatment method for municipal waste in Luxembourg, is carried out in the sole incinerator of the country where energy is recovered. Consequently, waste incineration related emissions are accounted for in CRF sector 1 – Energy (details in Chapters 3 and 8 respectively).

Energy production and consumption related GHG emissions have decreased by 14.0% between 1990 and 2015 from 10.2 Mio. t CO_2e in 1990 to 8.8 Mio. t CO_2e in 2015. For carbon dioxide, methane and nitrous oxide, the changes over the period 1990-2015 were -14.02%, +9.50% and +77.90%, respectively.

However, the overall trends at sector level hide very different developments at the CRF sub-category level. Within the energy sector, the fastest growing sub-sectors were **energy industries** (1A1) (due to the operational start of the TWINerg gas turbine in 2001) and **transport** (1A3): +1206.01% and +120.74%, respectively between 1990 and 2015 (-31.84% and -2.89% from 2014 to 2015) with, as a result, shares in the total energy related GHG emissions rising from 0.26% to 4.4% and 20.08% to 54.95%, respectively. For the other sub-sectors, the observed trends between 1990 and 2015 are -82.19% for **manufacturing industries and construction** (1A2), +15.63% for the **other sectors** (1A4), and +78.35% for **fugitive emissions from fuels** (1B). [70]

In fact, over the period, GHG emissions have been strongly influenced by varying fuel consumption levels in industry, in particular in the energy and the iron and steel industries, as well as in the road transport sector as percentage growths recorded for CRF sub-categories 1A1, 1A2 and 1A3 demonstrate. There are several industrial sites which had relatively high levels of GHG emissions, and which, therefore, have had a large impact on the national total of GHG emissions. The TWINerg power plant, and to a lesser extent several cogeneration (CHP) plants, also had an impact on the energy related GHG emissions, as already stressed in previous paragraphs. In the transport sector, road fuel consumption, and even more so road fuel sales, have a very important weight in the national energy balance, and, consequently, have also a very important impact on the total GHG emissions.

In the iron and steel industry, the passage from blast furnaces to electric arc furnaces allowed to significantly reducing GHG emissions between 1994 and 1998. Due to the importance of iron and steel industry in Luxembourg, this evolution hid many other emission trends between 1990 and 1998. After 1998, the increase of road fuel sales and, to a lesser extent, of electric energy production has led to a rather steep increase of GHG emissions in these sectors and, by extension, of the national total for GHG emissions.

All these changes briefly presented in the previous paragraphs completely modified the pattern of the energy related GHG emissions with regard to CRF sub-categories share (Figure 2-31) and to the "energy-mix" or fuel usage for energy production and consumption (Table 2-7 and Table 2-8; Figure 2-17 and Figure 2-18).

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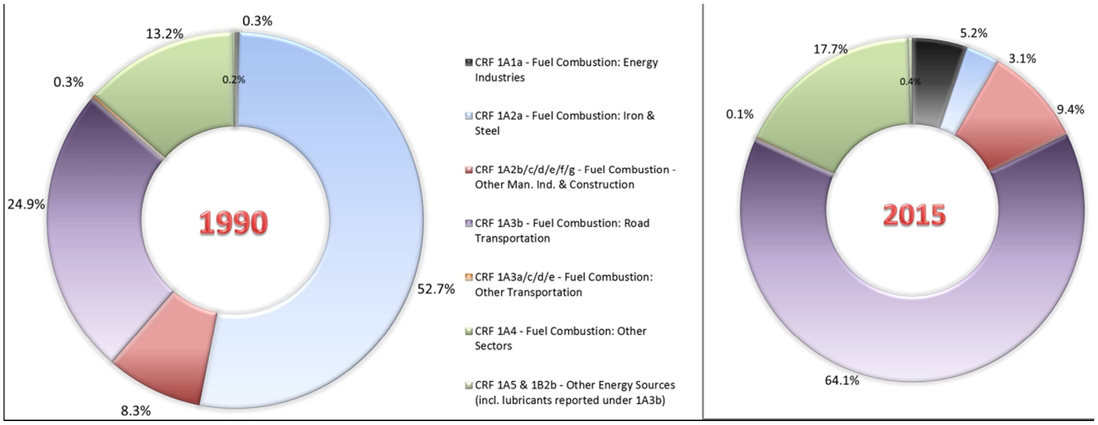
70 Fugitive emission growth is closely linked to natural gas use in Luxembourg.

Figure 2-31 – CRF sub-categories share in GHG emissions for CRF 1 – Energy: 1990 & 2015



Sources: Environment Agency and MDDI-DEV.

2.4.2 CRF 2 – Industrial Processes

GHG covered	CO_2 & F-gases		
Share in total GHG emissions, excl. LULUCF	***1990***	12.8% =	1 640.25 Gg CO_2e
	2015	6% =	626.08 Gg CO_2e

Industrial processes represent the third largest sector in Luxembourg with regard to GHG emissions. The sector includes emissions from industrial installations and from consumption of halocarbons, perfluorocarbons and SF_6 (the fluorinated gases or F-gases). In Luxembourg, when leaving F-gases out, only 3 companies and their various production installations are part of CRF sector 2:

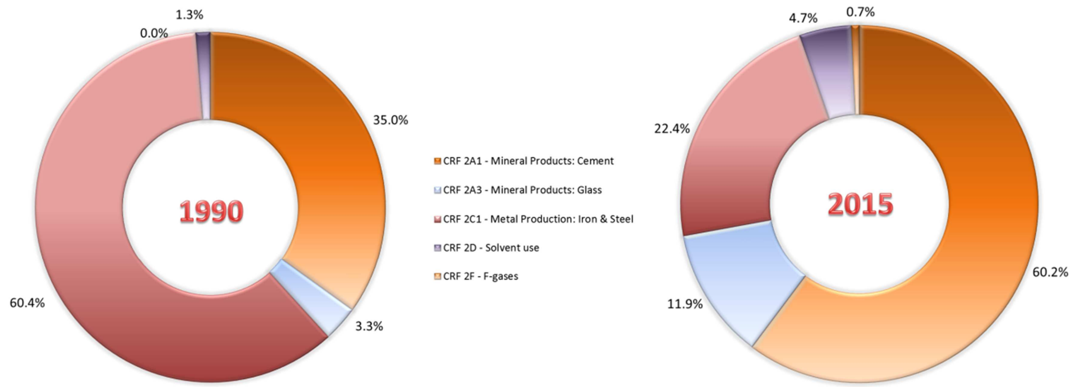
- CRF sub-categories 2A1 & 2A3: one cement works unit and one flat glass manufacturing company;
- CRF sub-category 2C1: the iron and steel manufacturing company ArcelorMittal.

Emissions from industrial processes show a declining trend between 1990 and 1998, then a relative stabilisation. This evolution was mainly driven by **process changes that occurred in the iron & steel industry**. As indicated above, this industry moved from blast to electric arc furnaces between 1994 and 1998. As a consequence, steel industry process emissions in CO_2e decreased by 93.8% over the period 1990-2015. Overall sector emissions in CO_2e fell by about 61.8% between 1990 and 2015, reducing the weight of this sector in total GHG emissions from 12.9% to 6.1% over the period. By gas, however, the picture is different. For carbon dioxide, the decrease over the period 1990-2015 was -66.5%: -36.7% for 2A1, +21.45% for 2A3 and -87.5% for 2C1. F-gases emissions, on the contrary, increased regularly: +285.46% over the period 1995-2015 but they are minor compared to the total emissions as Figure 2-31 shows.

The striking increase of **F-gases emissions** is the consequence of supposedly growing use in the country, notably due to an increasing use of air conditioning and noise reduction windows (see Section 4.7).

The emission trends briefly described in the previous paragraphs led to a significant change in the composition of industrial processes' GHG emissions: see Figure 2-32.

Figure 2-32 – CRF sub-categories share in GHG emissions for CRF 2 – Industrial Processes: 1990 & 2015



Sources: Environment Agency and MDDI-DEV.

2.4.3 CRF 3 – Agriculture

GHG covered	CH_4 & N_2O		
Share in total GHG emissions, excl. LULUCF	***1990***	5.56% =	714.41 Gg CO_2e
	2015	6.24% =	680.83 Gg CO_2e

Trends in agriculture were also favourable between 1990 and 2015: in general GHG related to agricultural activities have decreased by 6.2% (+1.6% for methane and -22.6% for nitrous oxide). Enteric Fermentation (3A) saw its emissions declining by 1.08%, whereas for agricultural soils (3D), the decrease reaches 22.56%. For manure management (3B), emissions increased by 9.0% between 1990 and 2015, though opposite variations are observed for the two GHG emitted by this activity: methane increased by 23.5% and nitrous oxide decreased by 10.2%.

However, the evolution of nitrous oxide emissions stemming from agricultural soils (3D) shapes the overall agriculture emission pattern. Indeed, for both the years 1990 and 2015, CRF category 3D is the biggest contributor to agriculture related emissions, though it is also, as for other Annex I Parties, the agriculture category that shows the highest uncertainty in the inventory. It is also worth noting that the shares of each CRF category under CRF sector 3 for which GHG emissions are reported have barely changed over the period: see Figure 2-33.

Looking at each CRF category in more detail, generally the decrease in **enteric fermentation** related **methane** emanations over the period 1990-2015 is mainly the result from declining emissions generated by cattle (-8.6%), whilst increasing emissions were recorded for the other livestock categories, except rabbits. With regard to cattle, its total population size declined throughout the period 1990-2015 driven by a decline in dairy cattle heads – non-dairy cattle population in 2015 is only 4.4% below its 1990 level. However, a shift did occur within the cattle population with a reduction for dairy cattle (-20%) and an increase for female mature non-dairy cattle (+18.8%). In fact, cattle population and its evolution are strongly influenced by changes in the agricultural policy and, more precisely, in the Common Agricultural Policy of the EU (*CAP*). Another factor influencing cattle population is, of course, meat and milk prices (which, themselves are affected by agricultural policy changes and targets).[71] Finally, if the dairy cattle population decreased by 20% between 1990 and 2015, related methane emissions only declined by 3.2%. This is explained by increasing milk yield over the period that, in turn, led to an augmentation of the gross energy intake for dairy cattle and, consequently, of the methane implied emission factors.

Looking at **methane** emissions from **manure management**, an increase by 23.5% can be observed for the period 1990-2015. Animals who contributed the most to these emissions were cattle and swine. As far as **nitrous oxide** emissions from **manure management** are concerned, a decrease of 10.2% is observed for the period 1990-2015. These emissions are mainly due to cattle. However, if cattle were responsible for 91% of manure related N_2O emissions in 1990, this share dropped to a bit less than 88% in 2015. This evolution is the result of a declining (dairy) cattle population at the same time as other farm animal categories saw their number grow and as liquid system share in the animal waste management systems (AWMS) more than doubled at the expense of solid storage systems.

Finally, **nitrous oxide** emissions from **agricultural soils** are mainly driven by:

- nitrogen input to soils (such as application of synthetic fertilizers and manure) as well as nitrogen fixed by crops or crop residues;
- nitrogen excretion on pasture, range and paddock;
- by indirect soil emissions due to atmospheric deposition as well as to nitrogen from fertilizers and animals that is lost through leaching and run-off.

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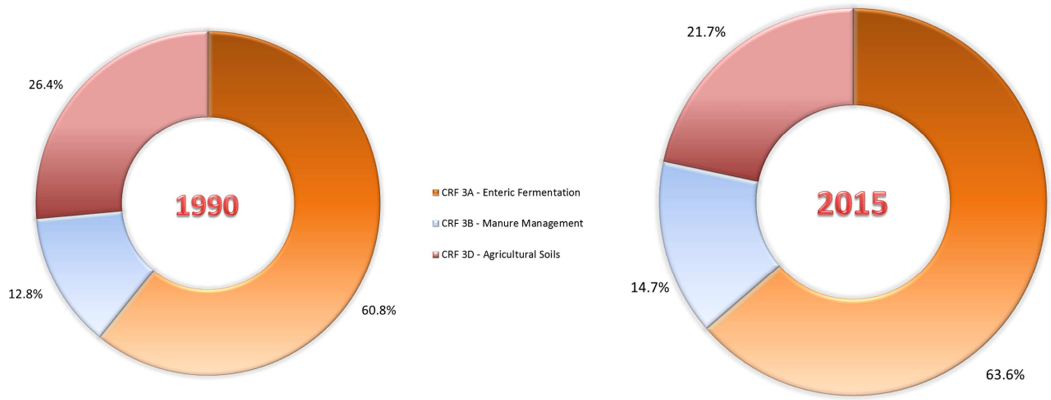
71 As an example, the peak in the non-dairy cattle population observed in 1991 can be explained by a sharp price fall of the bovine meat price that year. This price fall led farmers to postpone slaughtering until early 1992.

Figure 2-33 –CRF sub-categories share in GHG emissions for CRF 3 – Agriculture: 1990 & 2015



Source: MDDI-DEV.

2.4.4 CRF 5 – Waste

GHG covered	CH_4 & N_2O		
Share in total GHG emissions, excl. LULUCF	***1990***	0.88% =	111.92 Gg CO_2e
	2015	0.91% =	92.97 Gg CO_2e

In the waste sector, the main source of GHG was solid waste disposal on land (5A), but its weight decreased over the period 1990-2015 due to the combination of reduced amounts of waste disposed off in landfills and of increased emissions arising from composting activities (5D). However, GHG emission reduction for solid waste disposal on land between 1990 and 2015 (-44.5%) still drove a reduction for the overall waste sector despite composting rising emissions. Wastewater handling emissions (5D) experienced a 34.47% decline in emissions between 1990 and 2015. This decrease was driven by domestic and commercial wastewater treatment – and, more specifically methane related emissions – since industrial wastewater management remained fairly stable throughout the period.

For **solid waste disposal on land**, methane emissions have been reduced due to:

- a decrease in the quantity of waste being stored in authorised landfill sites (two as of today, three in the early 1990s), notably through the development of recycling schemes and the expansion of both the numbers of and the various waste categories collected by recycling centres;
- the aerobic pre-treatment before storage in one of the two landfill sites;
- the recent installation of methane recovery systems at waste dumping sites.

Wastewater treatment plant (WWTP) capacities expressed in population-equivalents have steadily grown since 1990. However, methane and nitrous oxide emissions decreased by 25% since 1990.

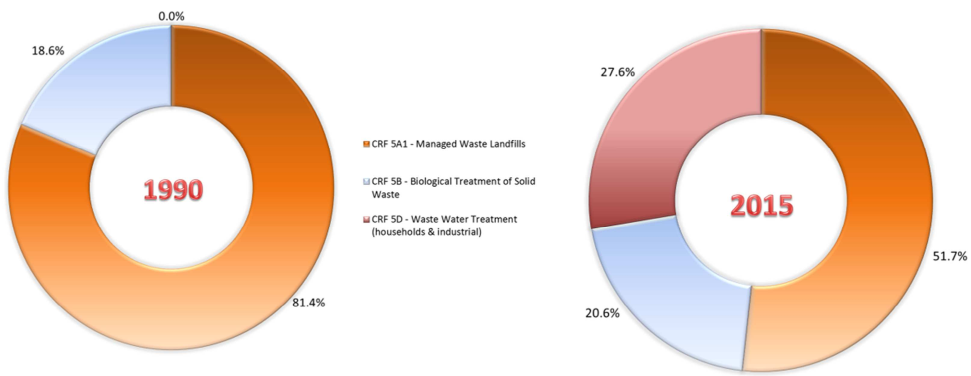
Therefore, technical changes, with regard to wastewater treatment, have had an undeniable role too.

Concerning **compost production**, this activity started on an "industrial scale" only in the early 1990s. It experienced a steady growth from 1993 to 2003 and then more or less stabilizes. Nowadays, 7 composting installations operate in Luxembourg, plus one that co-compost sewage sludge.[72] The latter uses active ventilation and fully operates aerobically – without methane formation. The other plants operate in part under anaerobic conditions, with a residence time in the "composter" of a few weeks.

It is recalled that waste incineration related emissions are part of CRF sub-category 1A1a (public electricity and heat production) since energy is recovered in the sole incinerator of the country and injected in the network.

The emission trends briefly described in the previous paragraphs led to a significant change in the composition of waste related GHG emissions: see Figure 2-34.

Figure 2-34 – CRF sub-categories share in GHG emissions for CRF 5 – Waste: 1990 & 2015



Sources: Environment Agency, Water Agency and MDDI-DEV.

2.4.5 CRF sectors – overview

The fact that the iron and steel industry has abandoned blast furnaces between 1994 and 1998, that the TWINerg power plant started fully its operations in 2002, and that fossil fuel consumption as well as road fuel sales have experienced a continuous increase up to 2005, hide many other emission trends and, due to their importance in the national total GHG emissions, they shape the overall pattern of Luxembourg's GHG emissions trend.

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72 See Table 8-17 in Section 8.5.2.2.

2.5 Description of Emission Trends of Indirect GHG and SO_2

Indirect GHG – NO_x, CO, NMVOCs – and SO_2 emissions as recorded in the inventory were extracted from the air pollutants emission inventory Luxembourg is compiling for the UNECE CLRTAP. Please refer to the Informative Inventory Report for more information on the estimation of the air pollutant emissions.[73]

2.6 Description of Emission Trends for the KP-LULUCF Inventory in Aggregate and by Activity, and by Gas

In Luxembourg, LULUCF was a net sink every year, except in 1990 and 1991.[74] An important sub-category is forest land, in particular its sub-source forest land remaining forest land (4A1). This sub-category, as well as the sub-category land converted to forest land (4A2), are net sinks for CO_2, whereas other categories and sub-categories reported in the inventory are generally sources of emissions (both CO_2 and N_2O).

The latest inventory shows potential net sinks over the second Kyoto commitment period 2013-2020. Indeed, from the "Accounting" KP-LULUCF table, the expected net carbon sequestration from LULUCF activities (or "Removal Units" – RMUs) reaches 528.85 Gg of CO_2e.[75] Consequently, forestry and land use changes will not contribute much to Luxembourg's means of meeting its Kyoto commitment. The latter would, therefore, be reached **mainly *via* national policies and measures and the use of "Kyoto flexible mechanisms"** and not *via* carbon sinks.

With regard to the KP-LULUCF activities, in 2015, CO_2 removals from **afforestation and reforestation** (AR) in Luxembourg amounted to -173.19 Gg CO_2. -123.67 Gg CO_2 resulted from accumulation of biomass, -4.78 Gg CO_2 resulted from accumulation of dead wood, -16.33 Gg CO_2 from accumulation of litter, -28.41 Gg CO_2 from accumulation of carbon stock in soils.

Emissions from **deforestation** (D) activities amounted in 2015 to 42.46 Gg CO_{2eq}. 17.01 Gg CO_{2eq} resulted from loss of biomass, 0.81 from loss of dead wood, 2.77 Gg CO_{2eq} from loss of litter, 21.88 Gg CO_{2eq} from loss of carbon stock in soils.

Due to the nature and permanence of ARD areas, there is from 1990 on:

- a steady increase in ARD areas, and related to that,
- a steady increase of removals and emissions, respectively, at these areas.

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73 http://www.ceip.at/ms/ceip_home1/ceip_home/status_reporting/2016_submissions/

74 Net emissions in 1990 and 1991 are the consequence of the important storms that severely hitted Luxembourg's forests in early 1989-90.

75 In the "Accounting" KP-LULUCF table, take the sum of A1 & A2, column "Accounting quantity", and divide it by 5: (-482.22+129.58)/5 = -70.5289 Gg or 0.0705289 Mt CO2e. In the SEF tables, no RMUs are accounted for yet).

3 Energy (CRF Sector 1)

3.1 Sector Overview

Emissions from this sector comprise emissions from fuel combustion activities (source category 1A) and fugitive emissions from fuels (source category 1B). For more details on categories where no emissions occur and categories that are not estimated or that are included elsewhere, please refer to Table 3-4.

Chapter 2 also includes information on and description of methodologies used for estimating GHG emissions as well as references to activity data and emission factors reported under CRF categories *1A – Fuel Combustion Activities* and *1B – Fugitive Emissions from Fuels* for the period 1990 to 2015.

GHG emissions from fossil fuel combustion are the main source of greenhouse gas emissions in the Grand-Duchy of Luxembourg. In 2015, about 86.03% of national total GHG emissions (excl. LULUCF) were caused by fossil fuel combustion activities in the energy and manufacturing industry, in the transportation sector and in the commercial and residential sector (category 1A). Fugitive emissions only made up about 0.34% of the national total GHG emissions (excl. LULUCF)

GHG emissions related to waste incineration are allocated to IPCC sub-category *1A1a – Fuel Combustion Activities – Energy Industries – Public Electricity and Heat Production* (see Section 3.2.6 of this chapter) since energy is recovered and injected into the public electricity and district heating networks.

Process related emissions are considered in CRF Sector *2 – Industrial Processes and Products Use* (see Chapter 4).

3.1.1 Emission Trends

Figure 3-1 and Table 3-1 show the GHG emission trends from 1990 to 2015 for each of the IPCC categories under CRF Sector *1 - Energy*, for which GHG emissions are reported. These are expressed in CO_2 equivalents and include CH_4 and N_2O emissions from biomass, but exclude CO_2 emissions from biomass combustion. CO_2 emissions from biomass combustion are reported under *Memory Items* and are not accounted for in the national total. GHG emissions from category *5C - Incineration and open burning of waste* are accounted for in sub-category *1A1a - Public Electricity and Heat Production*, as energy from waste burning is recovered and injected into the public electricity and district heating networks.

Fuel combustion activities (category 1A) related GHG emissions have decreased by 13.76% between 1990 and 2015 from 10.24 million tonnes CO_2 equivalents in 1990 to 8.83 million tonnes CO_2 equivalents in 2015. Carbon dioxide emissions decreased by 14.0% in 2015 compared to the base year. Methane emissions decreased by 40.7%, whereas nitrous oxide emissions increased by 77.9%, for the same period.

Figure 3-1 – GHG emission trends for CRF Sector 1-Energy: 1990-2015

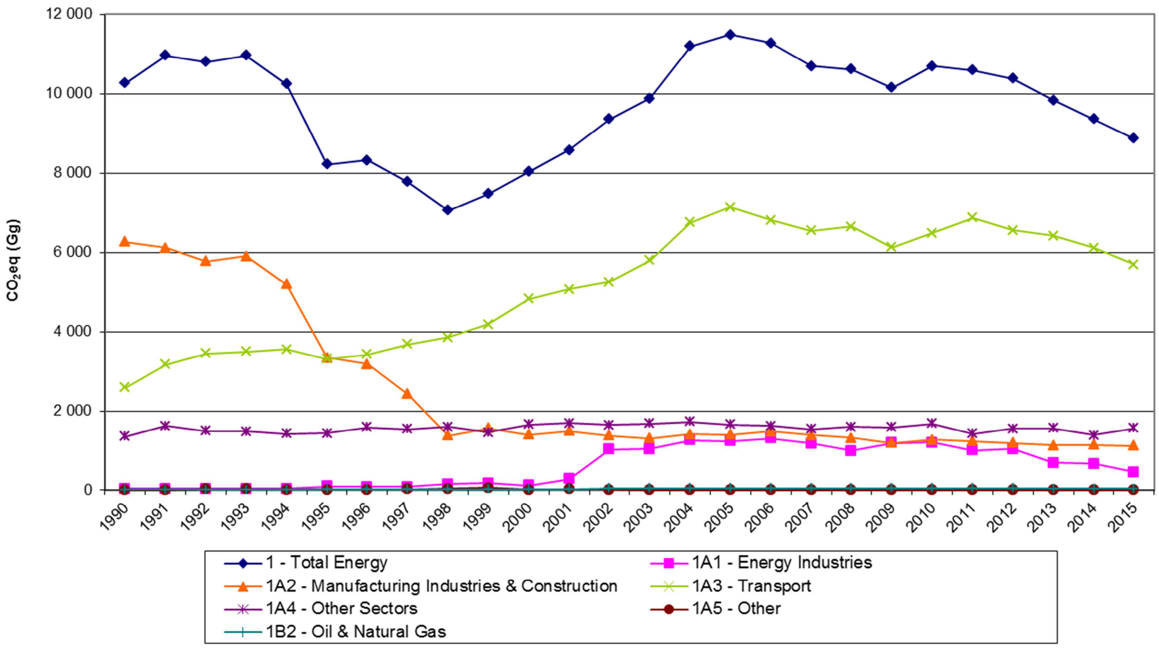


Figure 3-2 illustrates that the overall trend observed at sector level hides very different developments at the sub-category level. Indeed, between 1990 and 2015, GHG emissions have been strongly influenced by varying fuel consumption levels in industry, in particular in the iron and steel industry, as well as in the road transport sector as percentage growths recorded for sub-categories *1A2 – Manufacturing Industries and Construction* and *1A3 – Transport* demonstrate. There are several industrial sites which had relatively high levels of GHG emissions, and which, therefore, have had a large impact on the national total of GHG emissions. In the transport sector, road fuel consumption, and even more so road fuel sales[76], have a very important weight in the national energy balance, and, consequently, have also a very important impact on the total GHG emissions.

In the iron and steel industry, the technological change from blast furnaces to electric arc furnaces allowed reducing GHG emissions significantly between 1993 and 1997. Due to the importance of the iron and steel industry in Luxembourg, this evolution hid many other emission trends between 1990 and 1998. After 1998, the increase of road fuel sales and, to a lesser extent, the increase of electric energy production has led to a rather steep increase of GHG emissions in these sub-categories and, by extension, of the national total for GHG emissions. In more recent years, the

76 See Section 2.2.2 in Chapter 2.

closure of some industrial sites (mainly in the iron and steel industry), the decrease in local electricity production, a reduction in the road fuel sales and the implementation of energy efficiency measures in the building sector, led to a more or less steady decrease in emissions from 2005 onwards.

Table 3-1 – GHG emission trends in CO_2eq for CRF Sector 1 – Energy: 1990-2015

1 - Energy

GHG emissions by source & sink category (Gg)

Year	1A1 - Energy Industries				1A2 - Manufacturing Industries & Construction				1A3 - Transport				1A4 - Other Sectors			
	Total $CO_{2\,eq}$	CO_2 (excl. biomass)	CH_4 (incl. biomass)	N_2O (incl. biomass)	Total $CO_{2\,eq}$	CO_2 (excl. biomass)	CH_4 (incl. biomass)	N_2O (incl. biomass)	Total $CO_{2\,eq}$	CO_2 (excl. biomass)	CH_4 (incl. biomass)	N_2O (incl. biomass)	Total $CO_{2\,eq}$	CO_2 (excl. biomass)	CH_4 (incl. biomass)	N_2O (incl. biomass)
1990	35.64	*33.29*	*0.04*	*0.00*	6 265.38	*6 249.95*	*0.16*	*0.04*	2 584.67	*2 556.05*	*0.43*	*0.06*	1 355.67	*1 338.86*	*0.43*	*0.02*
1991	37.29	*34.83*	*0.04*	*0.01*	6 112.22	*6 096.36*	*0.15*	*0.04*	3 172.45	*3 138.61*	*0.47*	*0.07*	1 621.23	*1 602.75*	*0.48*	*0.02*
1992	37.19	*34.73*	*0.04*	*0.01*	5 773.57	*5 757.50*	*0.15*	*0.04*	3 448.48	*3 411.45*	*0.44*	*0.09*	1 494.09	*1 476.95*	*0.45*	*0.02*
1993	35.38	*33.04*	*0.04*	*0.00*	5 908.81	*5 892.13*	*0.15*	*0.04*	3 498.07	*3 460.08*	*0.38*	*0.10*	1 477.85	*1 460.78*	*0.45*	*0.02*
1994	34.61	*32.32*	*0.04*	*0.00*	5 196.12	*5 179.38*	*0.15*	*0.04*	3 553.59	*3 513.75*	*0.34*	*0.11*	1 418.98	*1 402.79*	*0.41*	*0.02*
1995	93.54	*91.29*	*0.03*	*0.00*	3 338.73	*3 324.81*	*0.10*	*0.04*	3 313.45	*3 275.79*	*0.29*	*0.10*	1 432.67	*1 416.24*	*0.42*	*0.02*
1996	82.35	*80.61*	*0.03*	*0.00*	3 184.91	*3 171.10*	*0.10*	*0.04*	3 422.95	*3 384.73*	*0.27*	*0.11*	1 583.43	*1 566.89*	*0.42*	*0.02*
1997	89.72	*87.66*	*0.03*	*0.00*	2 419.41	*2 406.43*	*0.08*	*0.04*	3 683.24	*3 644.81*	*0.25*	*0.11*	1 537.29	*1 520.90*	*0.41*	*0.02*
1998	155.93	*153.38*	*0.04*	*0.01*	1 373.69	*1 361.75*	*0.06*	*0.04*	3 860.99	*3 823.62*	*0.23*	*0.11*	1 602.58	*1 586.07*	*0.41*	*0.02*
1999	173.46	*170.54*	*0.05*	*0.01*	1 564.08	*1 550.71*	*0.06*	*0.04*	4 183.98	*4 146.70*	*0.21*	*0.11*	1 458.81	*1 443.10*	*0.39*	*0.02*
2000	120.17	*117.37*	*0.04*	*0.01*	1 396.92	*1 382.99*	*0.06*	*0.04*	4 817.63	*4 779.47*	*0.21*	*0.11*	1 653.35	*1 637.31*	*0.40*	*0.02*
2001	282.26	*279.33*	*0.05*	*0.01*	1 489.23	*1 474.29*	*0.07*	*0.04*	5 062.83	*5 025.60*	*0.19*	*0.11*	1 692.60	*1 676.06*	*0.42*	*0.02*
2002	1 029.32	*1 025.62*	*0.06*	*0.01*	1 374.78	*1 359.69*	*0.07*	*0.05*	5 250.27	*5 214.90*	*0.17*	*0.10*	1 639.89	*1 624.02*	*0.40*	*0.02*
2003	1 036.71	*1 032.90*	*0.06*	*0.01*	1 312.17	*1 297.60*	*0.06*	*0.04*	5 799.74	*5 764.62*	*0.16*	*0.10*	1 680.07	*1 664.22*	*0.40*	*0.02*
2004	1 257.41	*1 253.26*	*0.07*	*0.01*	1 408.41	*1 393.61*	*0.07*	*0.04*	6 755.54	*6 720.41*	*0.15*	*0.10*	1 727.98	*1 711.59*	*0.41*	*0.02*
2005	1 243.19	*1 239.18*	*0.07*	*0.01*	1 399.97	*1 384.22*	*0.10*	*0.04*	7 134.02	*7 099.29*	*0.13*	*0.11*	1 657.24	*1 641.64*	*0.39*	*0.02*
2006	1 305.28	*1 301.09*	*0.07*	*0.01*	1 477.50	*1 461.69*	*0.10*	*0.04*	6 816.70	*6 782.31*	*0.11*	*0.11*	1 622.75	*1 607.50*	*0.39*	*0.02*
2007	1 181.71	*1 177.54*	*0.07*	*0.01*	1 384.25	*1 368.79*	*0.10*	*0.04*	6 540.34	*6 502.22*	*0.10*	*0.12*	1 535.64	*1 521.52*	*0.36*	*0.02*
2008	996.00	*991.94*	*0.07*	*0.01*	1 324.36	*1 310.70*	*0.10*	*0.04*	6 649.12	*6 605.85*	*0.09*	*0.14*	1 599.27	*1 584.44*	*0.38*	*0.02*
2009	1 190.78	*1 186.67*	*0.07*	*0.01*	1 192.26	*1 180.01*	*0.08*	*0.03*	6 126.16	*6 083.26*	*0.08*	*0.14*	1 589.37	*1 574.05*	*0.40*	*0.02*
2010	1 205.97	*1 202.05*	*0.06*	*0.01*	1 271.99	*1 259.38*	*0.09*	*0.03*	6 485.63	*6 437.63*	*0.07*	*0.16*	1 685.92	*1 670.29*	*0.42*	*0.02*
2011	1 004.16	*1 000.20*	*0.06*	*0.01*	1 242.86	*1 230.86*	*0.09*	*0.03*	6 872.65	*6 818.83*	*0.06*	*0.18*	1 421.68	*1 408.74*	*0.34*	*0.02*
2012	1 042.72	*1 038.72*	*0.06*	*0.01*	1 186.12	*1 174.96*	*0.08*	*0.03*	6 554.98	*6 501.85*	*0.06*	*0.17*	1 547.46	*1 532.76*	*0.40*	*0.02*
2013	685.89	*682.30*	*0.06*	*0.01*	1 137.59	*1 126.32*	*0.08*	*0.03*	6 417.17	*6 363.40*	*0.05*	*0.18*	1 560.73	*1 545.54*	*0.42*	*0.02*
2014	668.52	*664.65*	*0.06*	*0.01*	1 150.22	*1 138.33*	*0.09*	*0.03*	6 118.37	*6 065.44*	*0.05*	*0.17*	1 383.95	*1 368.82*	*0.43*	*0.01*
2015	457.22	*453.05*	*0.07*	*0.01*	1 116.35	*1 105.38*	*0.08*	*0.03*	5 692.83	*5 642.56*	*0.04*	*0.17*	1 567.93	*1 552.32*	*0.44*	*0.02*
Trend 1990-2015	*1182.74%*	*1261.01%*	*79.81%*	*75.14%*	*-82.18%*	*-82.31%*	*-48.09%*	*-22.32%*	*120.25%*	*120.75%*	*-90.20%*	*176.33%*	*15.66%*	*15.94%*	*1.13%*	*-22.24%*
Trend 2014-2015	*-31.61%*	*-31.84%*	*6.49%*	*8.44%*	*-2.94%*	*-2.89%*	*-7.87%*	*-7.73%*	*-6.96%*	*-6.97%*	*-9.66%*	*-4.91%*	*13.29%*	*13.41%*	*2.45%*	*4.95%*

Note: Table continues on next page.

1 - Energy

GHG emissions by source & sink category (Gg)

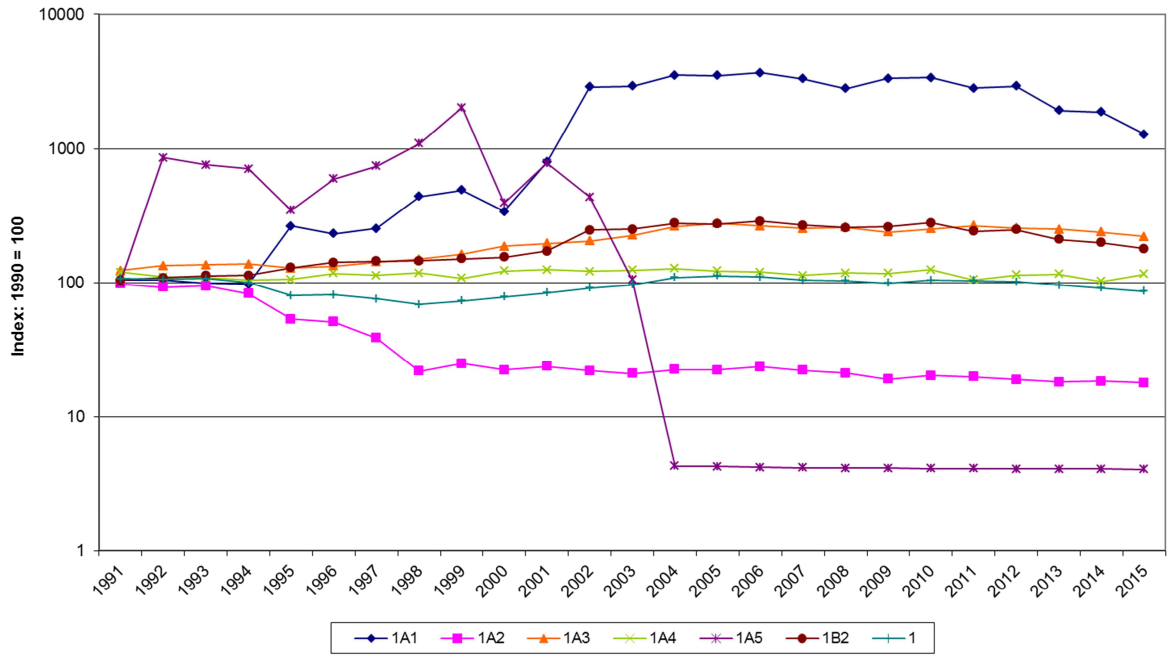
Year	1A5 - Other				1B2 - Oil & Natural Gas				1 - Total Energy			
	Total $CO_{2\ eq}$	CO_2 *(excl. biomass)*	CH_4 *(incl. biomass)*	N_2O *(incl. biomass)*	Total $CO_{2\ eq}$	CO_2 *(excl. biomass)*	CH_4 *(incl. biomass)*	N_2O *(incl. biomass)*	Total $CO_{2\ eq}$	CO_2 *(excl. biomass)*	CH_4 *(incl. biomass)*	N_2O *(incl. biomass)*
1990	3.12	*3.10*	*0.000*	*0.000*	19.39	*0.03*	*0.77*	*NA, NO*	10 263.87	*10 181.27*	*1.84*	*0.12*
1991	3.12	*3.10*	*0.000*	*0.000*	20.11	*0.03*	*0.80*	*NA, NO*	10 966.43	*10 875.67*	*1.95*	*0.14*
1992	26.80	*26.65*	*0.003*	*0.000*	20.99	*0.03*	*0.84*	*NA, NO*	10 801.12	*10 707.30*	*1.91*	*0.15*
1993	23.64	*23.50*	*0.003*	*0.000*	21.79	*0.03*	*0.87*	*NA, NO*	10 965.53	*10 869.56*	*1.89*	*0.16*
1994	22.05	*21.92*	*0.003*	*0.000*	21.94	*0.03*	*0.88*	*NA, NO*	10 247.29	*10 150.20*	*1.82*	*0.17*
1995	10.78	*10.71*	*0.001*	*0.000*	25.01	*0.03*	*1.00*	*NA, NO*	8 214.19	*8 118.88*	*1.85*	*0.16*
1996	18.53	*18.42*	*0.002*	*0.000*	27.36	*0.04*	*1.09*	*NA, NO*	8 319.54	*8 221.78*	*1.91*	*0.17*
1997	23.03	*22.91*	*0.003*	*0.000*	27.98	*0.04*	*1.12*	*NA, NO*	7 780.67	*7 682.75*	*1.89*	*0.17*
1998	34.10	*33.92*	*0.004*	*0.000*	28.20	*0.04*	*1.13*	*NA, NO*	7 055.50	*6 958.78*	*1.87*	*0.17*
1999	63.07	*62.73*	*0.008*	*0.000*	29.20	*0.04*	*1.17*	*NA, NO*	7 472.60	*7 373.83*	*1.89*	*0.17*
2000	12.21	*12.17*	*0.001*	*0.000*	29.98	*0.04*	*1.20*	*NA, NO*	8 030.26	*7 929.34*	*1.91*	*0.18*
2001	24.24	*24.16*	*0.002*	*0.000*	33.32	*0.04*	*1.33*	*NA, NO*	8 584.48	*8 479.49*	*2.06*	*0.18*
2002	13.54	*13.49*	*0.001*	*0.000*	47.72	*0.06*	*1.91*	*NA, NO*	9 355.53	*9 237.78*	*2.60*	*0.18*
2003	3.27	*3.25*	*0.000*	*0.000*	48.36	*0.06*	*1.93*	*NA, NO*	9 880.33	*9 762.66*	*2.61*	*0.18*
2004	0.13	*0.12*	*0.000*	*0.000*	53.67	*0.07*	*2.14*	*NA, NO*	11 203.15	*11 079.05*	*2.85*	*0.18*
2005	0.13	*0.12*	*0.000*	*0.000*	52.87	*0.07*	*2.11*	*NA, NO*	11 487.42	*11 364.51*	*2.80*	*0.18*
2006	0.13	*0.12*	*0.000*	*0.000*	55.48	*0.07*	*2.22*	*NA, NO*	11 277.84	*11 152.78*	*2.89*	*0.18*
2007	0.13	*0.12*	*0.000*	*0.000*	51.91	*0.07*	*2.07*	*NA, NO*	10 693.98	*10 570.25*	*2.69*	*0.19*
2008	0.13	*0.12*	*0.000*	*0.000*	49.64	*0.07*	*1.98*	*NA, NO*	10 618.52	*10 493.11*	*2.61*	*0.20*
2009	0.13	*0.12*	*0.000*	*0.000*	50.18	*0.07*	*2.00*	*NA, NO*	10 148.88	*10 024.18*	*2.63*	*0.20*
2010	0.13	*0.12*	*0.000*	*0.000*	53.96	*0.07*	*2.16*	*NA, NO*	10 703.60	*10 569.54*	*2.79*	*0.22*
2011	0.13	*0.12*	*0.000*	*0.000*	46.78	*0.06*	*1.87*	*NA, NO*	10 588.26	*10 458.81*	*2.42*	*0.23*
2012	0.13	*0.12*	*0.000*	*0.000*	47.85	*0.06*	*1.91*	*NA, NO*	10 379.26	*10 248.47*	*2.51*	*0.23*
2013	0.13	*0.12*	*0.000*	*0.000*	40.74	*0.05*	*1.63*	*NA, NO*	9 842.25	*9 717.73*	*2.24*	*0.23*
2014	0.13	*0.12*	*0.000*	*0.000*	38.47	*0.05*	*1.54*	*NA, NO*	9 359.67	*9 237.41*	*2.16*	*0.23*
2015	0.13	*0.12*	*0.000*	*0.000*	34.60	*0.05*	*1.38*	*NA, NO*	8 869.05	*8 753.47*	*2.01*	*0.22*
Trend 1990-2015	*-95.96%*	*-96.10%*	*-99.12%*	*-65.81%*	*78.46%*	*78.46%*	*78.46%*	*NA*	*-8.81%*	*-9.27%*	*17.82%*	*85.73%*
Trend 2014-2015	*-0.17%*	*0.02%*	*-2.37%*	*-4.45%*	*-10.07%*	*-10.07%*	*-10.07%*	*NA*	*-4.90%*	*-4.94%*	*-3.51%*	*-0.44%*

Source: Environment Agency.

Notes: CH_4 emissions are converted in CO_2eq by multiplying the emissions by 25, *i.e.* the global warming potential (GWP) value for methane based on the effects of GHG over a 100-year time horizon.

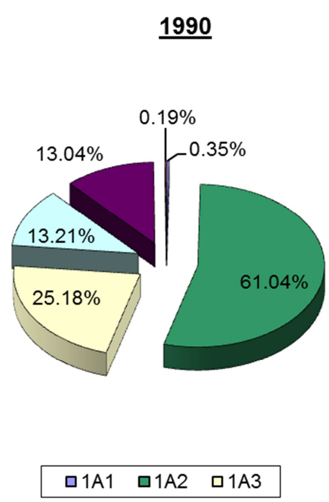
N_2O emissions are converted in CO_2eq by multiplying the emissions by 298, *i.e.* the global warming potential (*GWP*) value for nitrous oxide based on the effects of GHG over a 100-year time horizon.

Figure 3-2 – GHG emission trend indexes for CRF Sector 1 – Energy: 1990-2015



All the changes briefly presented in the previous paragraphs – as well as in Chapter 2 - completely modified the pattern of the energy related GHG emissions between 1990 and 2015 with regard to the share between sub-categories – see Figure 3-3 – and to the "energy-mix" or fuel use for energy production and consumption – see Table 3-2.

Figure 3-3 – IPCC sub-categories share in GHG emissions for CRF Sector 1 – Energy: 1990 and 2015



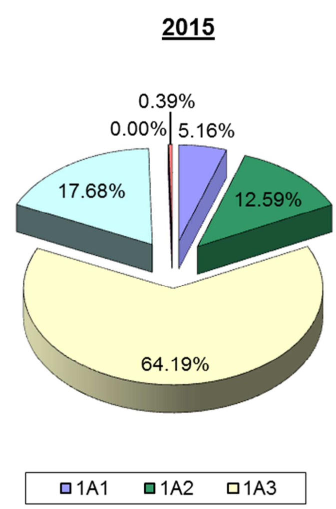


Table 3-2– Final energy consumption trends: 1990-2015

	TJ							
Year	**Total**	***Coal***	***Blast furnace gas***	***Natural gas (1)***	***Electricity***	***Heat (2)***	***Liquid fuels (3)***	***Wood & biomass***
1990	144 043	*34 332*	*8 457*	*19 427*	*14 989*	*NO*	*66 193*	*645*
1991	151 194	*30 815*	*7 235*	*20 390*	*15 198*	*NO*	*76 912*	*645*
1992	151 495	*29 475*	*6 196*	*21 227*	*15 282*	*NO*	*78 670*	*645*
1993	154 576	*30 689*	*6 514*	*22 064*	*15 826*	*NO*	*78 837*	*645*
1994	151 033	*27 268*	*5 504*	*21 990*	*16 747*	*126*	*78 754*	*645*
1995	134 632	*16 035*	*2 732*	*23 907*	*18 045*	*586*	*72 683*	*645*
1996	138 070	*15 671*	*2 512*	*26 251*	*17 710*	*547*	*74 734*	*645*
1997	136 435	*10 422*	*1 347*	*27 156*	*18 254*	*564*	*78 047*	*645*
1998	135 560	*4 883*	*NA*	*27 437*	*19 092*	*950*	*82 554*	*645*
1999	142 821	*4 836*	*NA*	*28 436*	*19 836*	*986*	*88 083*	*645*
2000	149 589	*4 595*	*NA*	*28 126*	*20 790*	*504*	*94 645*	*930*
2001	156 658	*4 958*	*NA*	*27 998*	*21 033*	*624*	*100 723*	*1 321*
2002	158 216	*3 084*	*NA*	*28 258*	*21 261*	*1 087*	*103 120*	*1 406*
2003	168 342	*2 369*	*NA*	*28 674*	*22 252*	*2 818*	*110 822*	*1 407*
2004	186 616	*3 329*	*NA*	*29 942*	*23 007*	*3 036*	*125 715*	*1 587*
2005	190 453	*3 249*	*NA*	*29 338*	*22 149*	*3 056*	*130 171*	*2 490*
2006	187 684	*3 877*	*NA*	*30 623*	*23 806*	*3 211*	*123 605*	*2 562*
2007	184 843	*3 280*	*NA*	*29 823*	*24 098*	*2 582*	*120 542*	*4 519*
2008	186 610	*3 137*	*NA*	*30 616*	*23 750*	*2 922*	*121 488*	*4 697*
2009	173 706	*2 801*	*NA*	*28 659*	*22 005*	*2 484*	*113 538*	*4 219*
2010	184 340	*2 807*	*NA*	*31 412*	*23 735*	*3 037*	*118 810*	*4 539*
2011	182 454	*2 443*	*NA*	*27 916*	*23 343*	*3 102*	*121 234*	*4 415*
2012	177 502	*2 250*	*NA*	*28 262*	*22 450*	*3 045*	*116 796*	*4 700*
2013	175 397	*2 006*	*NA*	*27 790*	*22 316*	*3 230*	*114 952*	*5 103*
2014	170 206	*2 235*	*NA*	*26 536*	*22 256*	*2 512*	*110 728*	*5 938*
2015	169 703	*2 053*	*NA*	*27 836*	*22 390*	*2 331*	*108 815*	*6 278*
Trend 1990-2015	*17.81%*	*-94.02%*	*NA*	*43.29%*	*49.38%*	*NA*	*64.39%*	*873.75%*
Share 1990	*100.00%*	*23.83%*	*5.87%*	*13.49%*	*10.41%*	*NA*	*45.95%*	*0.45%*
Share 2015	*100.00%*	*1.21%*	*NA*	*16.40%*	*13.19%*	*1.37%*	*64.12%*	*3.70%*

Source: STATEC: Statistical Yearbook, Table A4300: http://www.statistiques.public.lu/

Notes: (1) based on GCV

(2) heat from cogeneration, including heat recovery from waste incineration

(3) including blended biodiesel

Data extracted on 15th December 2016 (subject to change since that date)

Final energy consumption increased by 17.8% between 1990 and 2015 and passed through a minimum in 1995 and a maximum in 2005. All the energy sources have seen their consumption increase over the period, except coal and blast furnace gas, for which the declining use in the first part of the 1990s was closely related to the discontinuation of the use of blast furnaces in the iron & steel industry. Table 3-2 also shows the dramatic change in the "energy-mix" in Luxembourg between 1990 and 2015, with a dropping share of solid fuels – for which the main part was used in the iron and steel industry – in favour of liquid fuels and natural gas and, to a lesser extent, to new energy sources such as cogeneration and biomass. Biomass is expected to increase more rapidly in the future due to European commitments, also engaged by Luxembourg, to promote the use of biomass, especially solid biomass and biogas.

In 2015, with 64.1% of the final total energy consumption in Luxembourg, liquid fuels are the most important energy source, with diesel being the first liquid fuel in terms of volumes sold. The domestic liquid fuel consumption in Luxembourg is much lower than the level of fuel sales, because large amounts of road fuels are bought by cross-boarder commuters and transit traffic passing through Luxembourg and thus exported on board of road vehicle tanks. Actually, in 2015, 70% of road fuels sold on Luxembourg's territory are exported inside vehicle tanks and combusted abroad (see Table 3-59 in Section 3.2.8.3).

The importance of natural gas has increased constantly and significantly since 1990. In 2015, natural gas consumption ranked second after the consumption of liquid fuels. This development followed the continuous extension of the natural gas network in Luxembourg and the substantial increase of Luxembourg's population since 1990, and as such, natural gas becomes more and more the main fuel for heating purposes.

Natural gas has also become the main energy source of Luxembourg's national electricity production capacity[77]. In 1990, more than 90% of Luxembourg's electric energy consumption was imported. One medium size power plant of about 70 MW was owned by the iron & steel industry, and partially fed the public network when electricity was produced in excess. That power plant was mainly run on blast furnace gas and was phased out in 1997 after the last blast furnace went out of service.

In the early 1990s, small cogeneration plants appeared. Their installation was encouraged financially by the Government. This development was followed later by some industrial companies which installed gas turbines to produce electricity and heat simultaneously. In mid-2002, the TWINerg power plant – a 350MW gas turbine – started its operation, producing electricity only until 2010. From 2011 onwards, heat is also recovered and fed into a district heating network providing heat for the new developement site at Esch-Belval. The TWINerg plant was shut down in 2016. Almost all of these cogeneration plants run on natural gas. Gas oil remains, however, the emergency fuel in case of a natural gas supply disruption.

Table 3-3 summarises electricity production trends in Luxembourg since 1990.

[77] This cannot be seen in final energy consumption statistics but only in the primary energy consumption figures.

Table 3-3 – Electricity production trends: 1990-2015

Year	Electricity production (GWh)			
	Total	***Thermic*** *(1)*	***RES*** *(2)*	***Cogeneration (3)***
1990	626	*559*	*68*	*NO*
1991	676	*622*	*54*	*NO*
1992	662	*594*	*68*	*NO*
1993	670	*608*	*62*	*NO*
1994	625	*506*	*86*	*33*
1995	530	*347*	*81*	*102*
1996	474	*306*	*53*	*114*
1997	424	*214*	*92*	*118*
1998	406	*105*	*107*	*195*
1999	389	*52*	*132*	*205*
2000	415	*51*	*144*	*219*
2001	869	*457*	*143*	*269*
2002	2 817	*2 333*	*131*	*352*
2003	2 784	*2 285*	*102*	*397*
2004	3 374	*2 787*	*144*	*442*
2005	3 337	*2 737*	*155*	*445*
2006	3 519	*2 866*	*182*	*471*
2007	3 190	*2 599*	*192*	*399*
2008	2 713	*2 089*	*202*	*422*
2009	3 143	*2 571*	*181*	*390*
2010	3 224	*2 607*	*176*	*440*
2011	2 644	*2 049*	*148*	*447*
2012	2 746	*2 104*	*204*	*438*
2013	1 843	*1 157*	*269*	*417*
2014	1 918	*1 241*	*296*	*381*
2015	1 350	*680*	*320*	*350*
Trend 1990-2015	*115.58%*	*21.69%*	*374.29%*	*NA*
Share 1990	*100.00%*	*89.22%*	*10.78%*	*NA*
Share 2015	*100.00%*	*50.36%*	*23.72%*	*25.92%*

Sources: STATEC: Statistical yearbook, Table A.4203: http://www.statistiques.public.lu

Notes:

(1) includes public thermal power plants (TWINerg), autoproducer thermal power plants and MSW incineration.

(2) RES = Renewable Energy Sources, includes small hydro-electric power plants, wind power, photovoltaic power.

(3) Cogeneration includes biomethanisation

Data extracted on Dec 16 2016 (subject to changes since that date)

3.1.2 Completeness

Table 3-4 gives an overview of the IPCC categories included under CRF Sector *1-Energy* and provides information on the status of emission estimates of all sub-categories.

Table 3-4 – Overview of CRF Sector 1 – Energy: status of emission estimates for CO_2, CH_4 and N_2O

GHG source & sink category	Description	Status CO_2	Status CH_4	Status N_2O
1A1a	fuel combustion activities – energy industries – public electricity & heat production	X	X	X
1A1b	fuel combustion activities – energy industries – petroleum refining	NO	NO	NO
1A1c	fuel combustion activities – energy industries – manufacture of solid fuels and other energy industries	NO	NO	NO
1A2a	fuel combustion activities – manufacturing industries & construction – iron & steel	X	X	X
1A2b	fuel combustion activities – manufacturing industries & construction – non-ferrous metals	X	X	X
1A2c	fuel combustion activities – manufacturing industries & construction – chemicals	X	X	X
1A2d	fuel combustion activities – manufacturing industries & construction – pulp, paper & print	X (2000-2015)	X (2000-2015)	X (2000-2015)
1A2e	fuel combustion activities – manufacturing industries & construction – food processing, beverages & tobacco	X	X	X
1A2f	fuel combustion activities – manufacturing industries & construction – non-metallic minerals	X	X	X
1A2g	fuel combustion activities – manufacturing industries & construction – other	X	X	X
1A3a	fuel combustion activities – transport – civil aviation	X	X	X
1A3b	fuel combustion activities – transport – road transportation	X	X	X
1A3c	fuel combustion activities – transport – railways	X	X	X
1A3d	fuel combustion activities – transport – navigation	X	X	X
1A3e	fuel combustion activities – transport – other transportation	NO	NO	NO
1A4a	fuel combustion activities – other sectors – commercial/institutional	X	X	X
1A4b	fuel combustion activities – other sectors – residential	X	X	X
1A4c	fuel combustion activities – other sectors – agriculture/forestry/fish farms	X	X	X
1A5a	fuel combustion activities – non-specified – stationary	X (1990-2003)	X (1990-2003)	X (1990-2003)
1A5b	fuel combustion activities – non-specified – mobile	X	X	X
1B1a	fugitive emissions from fuels – solid fuels – coal mining & handling	NO	NO	NO
1B1b	fugitive emissions from fuels – solid fuels – solid fuel transformation	NO	NO	NO
1B1c	fugitive emissions from fuels – solid fuels – other	NO	NO	NO
1B2a	fugitive emissions from fuels – oil & natural gas – oil	NA	NA	NO
1B2b	fugitive emissions from fuels – oil & natural gas – natural gas	X	X	
1B2c	fugitive emissions from fuels – oil & natural gas – venting & flaring	NO	NO	NO
1B2d	fugitive emissions from fuels – oil & natural gas – other	NA	NA	NA
Memo Items	international bunkers – aviation	X	X	X
Memo Items	international bunkers – marine	X	X	X
Memo Items	multilateral operations	NA	NA	NA
Memo Items	CO2 emissions from biomass	X		

Note: **X** indicates that emissions from this sub-category have been estimated, the grey shaded cells are those also shaded in the CRF tables.

3.2 Fuel Combustion Activities (1.A)

In 2015, GHG emissions of category *1A - Fuel Combustion* amounted to a total of 8.83 million tonnes CO_2eq (see Table 3-5). The transport sector (*1A3 - Transport*) represented the most important source, with a share of 64.44% of the GHG emissions within category *1A* (52.93% of national total excl. LULUCF). These emissions include emissions from fuel export, *i.e.* fuel bought by foreign commuters and transit traffic, but mostly emitted outside of Luxembourg's territory.

Combustion in the commercial and residential sector (*1A4 - Other Sectors*) was the second largest source of emissions with a share of 17.75% of the GHG emissions within category *1A* (14.58% of national total excl. LULUCF), followed by the industrial sector (*1A2 - Manufacturing Industries and Construction*) and the energy sector (*1A1 - Energy*) with shares of 12.64% and 5.18%, respectively (10.38% and 4.25% of national total excl. LULUCF, respectively). Emissions from sub-category *1A5*

- *Other*, which includes emissions from other non-specified sources, represented only 0.001% of the GHG emissions within category *1A* in 2015.

Table 3-5 - GHG emission trends and shares of 1A-Fuel combustion

1A - Fuel Combustion						
GHG emissions by source category excluding CO_2 emissions from biomass ($CO_{2\ eq}$ Gg)						
Year	**1A1 Energy Industries**	**1A2 Manufacturing Industries & Construction**	**1A3 Transportation**	**1A4 Other Sectors**	**1A5 Other**	**1A Fuel Combustion**
1990	*35.6*	*6 265.4*	*2 584.7*	*1 355.7*	*3.1*	10 244.5
1991	*37.3*	*6 112.2*	*3 172.4*	*1 621.2*	*3.1*	10 946.3
1992	*37.2*	*5 773.6*	*3 448.5*	*1 494.1*	*26.8*	10 780.1
1993	*35.4*	*5 908.8*	*3 498.1*	*1 477.9*	*23.6*	10 943.7
1994	*34.6*	*5 196.1*	*3 553.6*	*1 419.0*	*22.1*	10 225.4
1995	*93.5*	*3 338.7*	*3 313.5*	*1 432.7*	*10.8*	8 189.2
1996	*82.4*	*3 184.9*	*3 423.0*	*1 583.4*	*18.5*	8 292.2
1997	*89.7*	*2 419.4*	*3 683.2*	*1 537.3*	*23.0*	7 752.7
1998	*155.9*	*1 373.7*	*3 861.0*	*1 602.6*	*34.1*	7 027.3
1999	*173.5*	*1 564.1*	*4 184.0*	*1 458.8*	*63.1*	7 443.4
2000	*120.2*	*1 396.9*	*4 817.6*	*1 653.3*	*12.2*	8 000.3
2001	*282.3*	*1 489.2*	*5 062.8*	*1 692.6*	*24.2*	8 551.2
2002	*1 029.3*	*1 374.8*	*5 250.3*	*1 639.9*	*13.5*	9 307.8
2003	*1 036.7*	*1 312.2*	*5 799.7*	*1 680.1*	*3.3*	9 832.0
2004	*1 257.4*	*1 408.4*	*6 755.5*	*1 728.0*	*0.1*	11 149.5
2005	*1 243.2*	*1 400.0*	*7 134.0*	*1 657.2*	*0.1*	11 434.6
2006	*1 305.3*	*1 477.5*	*6 816.7*	*1 622.7*	*0.1*	11 222.4
2007	*1 181.7*	*1 384.2*	*6 540.3*	*1 535.6*	*0.1*	10 642.1
2008	*996.0*	*1 324.4*	*6 649.1*	*1 599.3*	*0.1*	10 568.9
2009	*1 190.8*	*1 192.3*	*6 126.2*	*1 589.4*	*0.1*	10 098.7
2010	*1 206.0*	*1 272.0*	*6 485.6*	*1 685.9*	*0.1*	10 649.6
2011	*1 004.2*	*1 242.9*	*6 872.7*	*1 421.7*	*0.1*	10 541.5
2012	*1 042.7*	*1 186.1*	*6 555.0*	*1 547.5*	*0.1*	10 331.4
2013	*685.9*	*1 137.6*	*6 417.2*	*1 560.7*	*0.1*	9 801.5
2014	*668.5*	*1 150.2*	*6 118.4*	*1 384.0*	*0.1*	9 321.2
2015	*457.2*	*1 116.3*	*5 692.8*	*1 567.9*	*0.1*	8 834.5
Trend 1990-2015	*1182.74%*	*-82.18%*	*120.25%*	*15.66%*	*-95.96%*	*-13.76%*
Share 1990	*0.35%*	*61.16%*	*25.23%*	*13.23%*	*0.03%*	*100.00%*
Share 2015	*5.18%*	*12.64%*	*64.44%*	*17.75%*	*0.00%*	*100.00%*

Table 3-6 presents the key source categories of *1A – Fuel Combustion Activities*.

Table 3-6 – Key categories of *1A – Fuel Combustion Activities*

1 - Energy *Key sources*							
IPCC Category	**Category Name**	**Fuel**	**GHG**	**LA excl. LULUCF**	**LA incl. LULUCF**	**TA excl. LULUCF**	**TA incl. LULUCF**
1A1	Energy Industries	gaseous	CO_2	98-99,01-15	02-15		
1A1	Energy Industries	other	CO_2	98, 11-15			X
1A1	Energy Industries	other	CH_4				X
1A1	Energy Industries	other	N_2O				X
1A1	Energy Industries	biomass	CH_4				X
1A1	Energy Industries	biomass	N_2O				X
1A2	Manufacturing Industries and Construction	gaseous	CO_2	90-15	90-15	X	
1A2	Manufacturing Industries and Construction	liquid	CO_2	90-15	90-91, 10-11		
1A2	Manufacturing Industries and Construction	solid	CO_2	90-15	90-97, 10-11	X	X
1A2	Manufacturing Industries and Construction	liquid	CH_4				X
1A2	Manufacturing Industries and Construction	solid	CH_4				X
1A3a	Aviation	aviation gasoline	CO2				X
1A3b	Road Transportation	diesel oil	CO_2	90-15	90-15	X	
1A3b	Road Transportation	gasoline	CO_2	90-15	90-15	X	
1A3b	Road Transportation	gasoline	CH_4				X
1A3b	Road Transportation	LPG	CH_4				X
1A3b	Road Transportation	gasoline	N_2O				X
1A3b	Road Transportation	LPG	N_2O				X
1A3c	Navigation	liquid	CH_4				X
1A3c	Navigation	liquid	N_2O				X
1A4	Other Sectors	gaseous	CO_2	90-15	90-91, 95-15	X	
1A4	Other Sectors	liquid	CO_2	90-15	90-15		
1A5	Other	liquid	CO_2	99			X

Sources: Environment Agency

Notes: LA = Level Assessment including respectively excluding LULUCF

TA = Trend Assessment including respectively excluding LULUCF

3.2.1 Comparison of the sectoral approach with the reference approach

This section provides a comparative analysis of the reference approach and the sectoral approach, and gives explanations for the differences between the two approaches. Figure 3-4 and

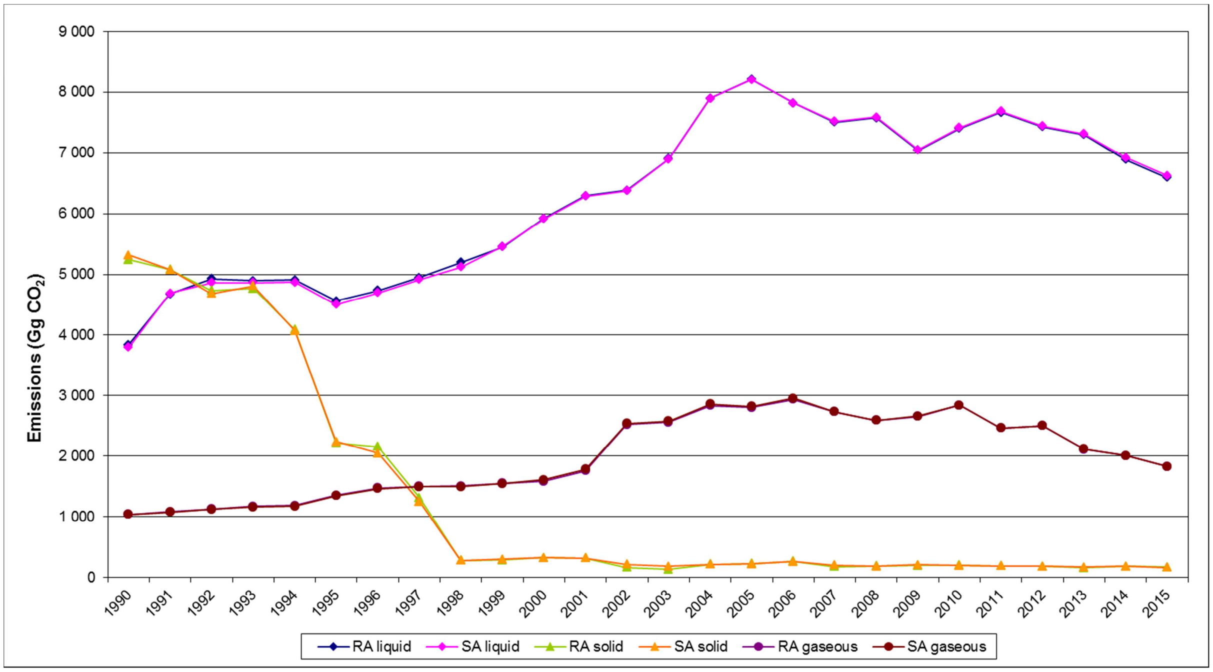


Table 3-7 present CO_2 emissions obtained by the sectoral and the reference approaches. The difference for total CO_2 emissions from fuel combustion varies between -0.71% and +1.98% throughout the time-series.

Figure 3-4 - CO_2 emissions obtained with Reference and Sectoral Approach

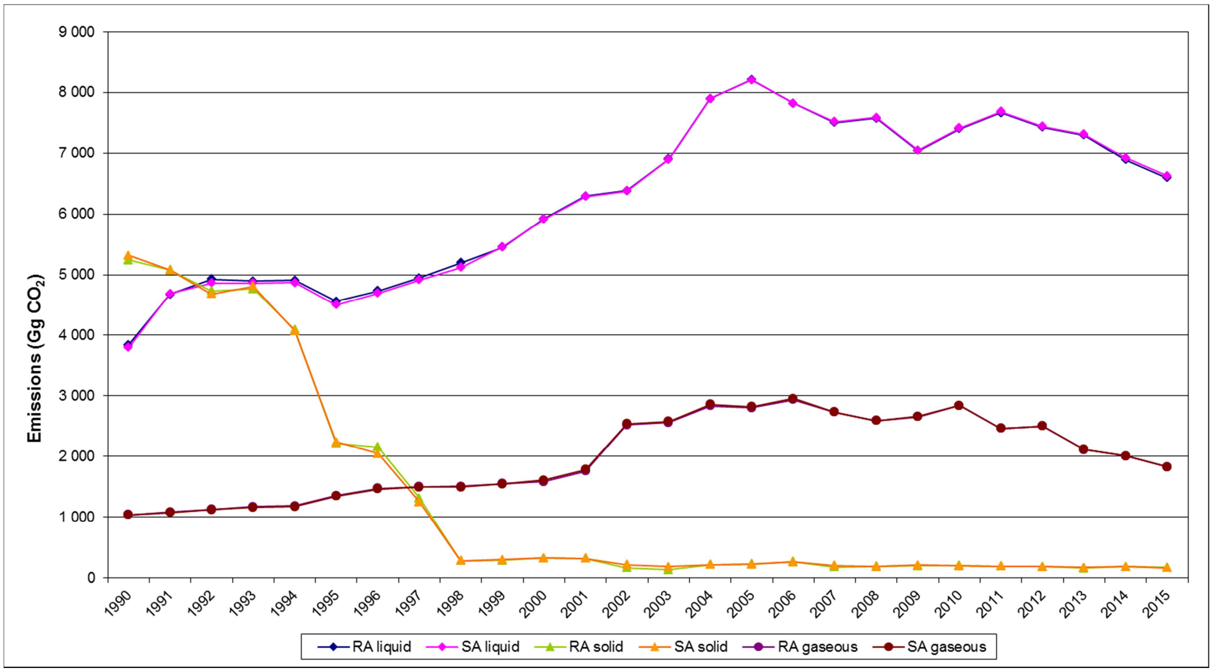


Table 3-7 – CO_2 emissions obtained with Reference and Sectoral Approach

Year	Reference Approach					Sectoral Approach				
	Liquid	Solid	Gaseous	Other	Total	Liquid	Solid	Gaseous	Other	Total
	[Gg CO_2]	[Gg CO_2]	[Gg CO_2]	[Gg CO_2]	[Gg CO_2]	[Gg CO_2]	[Gg CO_2]	[Gg CO_2]	[Gg CO_2]	[Gg CO_2]
1990	3 844	5 241	1 039	33	**10 156**	3 795	5 317	1 036	33	**10 181**
1991	4 675	5 081	1 080	35	**10 872**	4 689	5 077	1 074	35	**10 876**
1992	4 927	4 733	1 128	35	**10 823**	4 865	4 686	1 122	35	**10 707**
1993	4 898	4 768	1 173	33	**10 871**	4 863	4 813	1 161	33	**10 870**
1994	4 905	4 093	1 184	32	**10 214**	4 871	4 073	1 174	32	**10 150**
1995	4 559	2 209	1 351	31	**8 151**	4 506	2 239	1 343	31	**8 119**
1996	4 733	2 155	1 472	24	**8 384**	4 693	2 043	1 461	24	**8 222**
1997	4 944	1 315	1 500	28	**7 787**	4 916	1 247	1 491	28	**7 683**
1998	5 197	280	1 506	65	**7 048**	5 118	280	1 495	65	**6 959**
1999	5 456	287	1 552	73	**7 369**	5 458	296	1 546	73	**7 374**
2000	5 924	328	1 580	77	**7 909**	5 918	325	1 609	77	**7 929**
2001	6 292	320	1 758	97	**8 467**	6 286	317	1 781	97	**8 479**
2002	6 384	165	2 519	104	**9 172**	6 378	215	2 540	104	**9 238**
2003	6 904	133	2 556	102	**9 695**	6 898	187	2 576	102	**9 763**
2004	7 901	218	2 837	110	**11 066**	7 897	213	2 859	110	**11 079**
2005	8 214	228	2 803	107	**11 352**	8 209	224	2 824	107	**11 364**
2006	7 824	264	2 937	115	**11 140**	7 820	260	2 958	115	**11 153**
2007	7 505	178	2 731	116	**10 530**	7 519	204	2 731	116	**10 570**
2008	7 575	189	2 594	124	**10 482**	7 588	186	2 594	124	**10 493**
2009	7 046	199	2 657	102	**10 004**	7 053	211	2 658	102	**10 024**
2010	7 404	202	2 841	112	**10 560**	7 417	199	2 842	112	**10 569**
2011	7 665	191	2 463	116	**10 435**	7 688	191	2 464	116	**10 459**
2012	7 432	184	2 499	118	**10 233**	7 445	185	2 500	118	**10 248**
2013	7 300	160	2 112	118	**9 690**	7 313	173	2 113	118	**9 718**
2014	6 894	183	2 004	126	**9 207**	6 921	186	2 004	126	**9 237**
2015	6 594	168	1 827	129	**8 718**	6 631	165	1 828	129	**8 753**

Table 3-8 presents the relative difference of CO_2 emissions between reference and sectoral approach.

Table 3-8 – Difference of CO_2 emissions by type of fuel

Difference of CO_2 emissions between sectoral and reference approach [%]					
Year	*Solid*	*Liquid*	*Gaseous*	*Other*	Total
1990	- 1.44	1.29	0.27	0.00	- 0.25
1991	0.08	- 0.29	0.57	0.00	- 0.03
1992	1.01	1.27	0.59	0.00	1.08
1993	- 0.93	0.71	1.06	0.00	0.02
1994	0.48	0.69	0.92	0.00	0.63
1995	- 1.33	1.19	0.62	0.00	0.39
1996	5.49	0.84	0.75	0.00	1.98
1997	5.41	0.58	0.56	0.00	1.36
1998	0.02	1.53	0.74	0.00	1.29
1999	- 3.04	- 0.04	0.38	0.00	- 0.07
2000	0.94	0.10	- 1.82	0.00	- 0.26
2001	1.15	0.11	- 1.27	0.00	- 0.15
2002	- 23.52	0.10	- 0.83	0.00	- 0.71
2003	- 28.75	0.08	- 0.76	0.00	- 0.69
2004	2.18	0.06	- 0.77	0.00	- 0.12
2005	1.67	0.06	- 0.74	0.00	- 0.11
2006	1.72	0.05	- 0.72	0.00	- 0.12
2007	- 13.02	- 0.19	0.00	0.00	- 0.38
2008	1.43	- 0.17	- 0.01	0.00	- 0.10
2009	- 5.63	- 0.11	- 0.03	0.00	- 0.20
2010	1.54	- 0.17	- 0.02	0.00	- 0.09
2011	- 0.15	- 0.29	- 0.04	0.00	- 0.22
2012	- 0.83	- 0.18	- 0.02	0.00	- 0.15
2013	- 7.27	- 0.19	- 0.07	0.00	- 0.28
2014	- 1.35	- 0.39	- 0.03	0.00	- 0.32
2015	1.56	- 0.56	- 0.04	0.00	- 0.40

Source: Environment Agency
Note: Positive numbers indicate that CO_2 emissions from the reference approach are higher than emissions from the sectoral approach.

3.2.1.1 Methodology and data sources

The reference approach was compiled based on the 2006 IPCC Guidelines.

The primary data source for production, import, export, stock change, international bunker of fuels was the national energy balance and /or the IEA Energy questionnaires as provided and compiled by the national statistics office (STATEC).

NCVs, CO_2 emission factors and oxidation factors are identical to those used for the sectoral approach, if not otherwise stated in the CRF tables' documentation box.

The amount of carbon which does not lead to fuel combustion emissions was excluded from total carbon. Indeed, carbon excluded from fuel combustion is either emitted in another sector of the inventory (for example as an industrial process emission) or stored in the product manufactured from the fuel.

3.2.1.2 Explanation of differences

The following reasons provide explanations to the differences recorded between the Sectoral Approach and the Reference Approach (CRF table 1.A (b) and 1.A(c)):

- The sectoral approach is based on a combined bottom-up (using plant specific data where available) & top-down (national energy balance) approach. For some IPCC sub-categories, bottom-up activity data is higher than reported by the energy balance. In order to avoid potential underestimation, it is preferred to use the highest data whenever possible. Hence, emissions as calculated in the sectoral approach can be higher than the ones calculated in the reference approach. Please refer to section 3.2.5 for more details on the methodology applied to calculate emissions in the sectoral approach.
- Liquid fuels: difference in CO_2 emissions between the two approaches is about -0.6%, which lies under the 2% significance threshold.
- Solid fuels: difference in CO_2 emissions between the two approaches is about 1.6% for 2015, which lies under the 2% significance threshold. However, for some years there is a significant difference between both approaches (up to 28.75% for 2003). The most likely reason for these differences is that solid fuels are often stored in large quantities, and not immediately combusted after acquisition (sometimes combustion may even occur in a different calendar year).
- Gaseous fuels: difference in CO_2 emissions between the two approaches is about -0.04%, which lies under the 2% significance threshold.
- Other Fossil Fuels: This category is composed of three dominating facilities, all covered under the emission trading scheme (ETS). One facility is using secondary fossil fuels such as tires, fluff, waste solvents and sewage sludge as a replacement of standard solid fossil fuels such as coal for its clinker production. The activity data for these secondary fossil fuels, as used in the sectoral approach, are extracted from the ETS reports. However the national energy balance, used for the reference approach, does not report the consumption of such fuels. Hence, the CO_2 emission of these secondary fossil fuels was added to the reference approach, and the difference between the two approaches tends to 0%.

3.2.1.3 Category-specific recalculations including changes made in response to the review process

Table 3-9 presents the main revisions and recalculations done since submission 2016v1 relevant to the *Reference Approach*. For the quantitative aspect of these recalculations, please refer to Chapter 10.

Table 3-9 – Recalculations for the Reference Approach

GHG source & sink category	Revisions 2016v1 → 2017v1.2	Type of revision
All fuels	AD was revised according to the revised energy balance and IEA Questionnaires as provided by STATEC	updated AD
Consistency	Other fossil fuels: added CO_2 emission from other fossil fuels, as estimated for category 1A2f to the reference approach, as national energy balance does not include the consumption of these fuels.	Added fuel type
carbon contents / other parameters	All parameters and carbon contents were revised, if necessary, according to the 2006 IPPC Guidelines.	updated parameters

Major revisions in the energy balance have been made for natural gas allocated to the categories 1.A.2 – Manufacturing industries and construction and 1.A.4 – Other sectors for the years 2000-2014. In Luxembourg's previous submissions there was a relatively large difference (around 5%) between the reference approach and the sectoral approach for natural gas allocated to 1.A.2.f – Non-metallic minerals. Indeed, the amount of natural gas allocated to 1.A.2.f – Non-metallic minerals in the national energy balance was significantly lower than the amount determined by a bottom-up approach based on ETS data. The same situation was observed for other sub-sectors, such as the iron and steel industry. The reason for these differences was the following: the physical amounts of natural gas allocated to the different industry sectors in the national energy balance are based on company surveys inquiring the financial expenses for energy consumption. These financial amounts are then converted into physical amounts by applying a sector-specific standardized energy price. However, if the companies buy their energy at a much lower price than assumed by the national statistics institute, then the physical amount attributed to these companies is too low, which has been the case here for the glass industry. During discussions the inventory team had with the national statistics institute, this problem was acknowledged, and a solution has been developed for allocating the natural gas amounts consumed by the industry in a more realistic way by taking into account ETS declarations. This resulted in an important recalculation of natural gas activity data in the sectors 1.A.2 – Manufacturing industries and construction and 1.A.4 – Other sectors for the years 2000-2014 in the sectoral approach. As a result, the difference between the reference approach and the sectoral approach is now very low for gaseous fuels.

3.2.1.4 Planned improvements

Table 3-10 lists the main improvements planned for the next submission.

Table 3-10 – Planned improvements for the Reference Approach

GHG source & sink category	Planned improvement
Quantitative assessment	Provide a quantitative estimate of each separate discrepancy between RA and SA as outlined in Section 3.2.1.2.
Consistency	Improve consistency between the reference and sectoral approaches: fuel consumption of international bunkers - marine need to be subtracted from the reference approach where it is still included (ARR 2013, §22).

3.2.2 International Bunker Fuels

In 2015, GHG emissions from International Bunkers amounted to 1414 Gg CO_2e (see Table 3-11), an increase of approximately 247% compared to 1990, which is mainly due to increased international aviation activities.

Table 3-11 – Activity data and GHG emissions for International Bunkers

International Bunkers - Aviation & Marine												
Activity Data (GJ) and GHG emissions by source & sink category (Gg)												
Year	**Aviation (Kerosene & Aviation Gasoline)**					**Marine (Gas Oil)**					**Total Activity**	**Total $CO_{2\,eq}$**
	Activity (GJ)	**Total $CO_{2\,eq}$**	***CO_2***	***CH_4***	***N_2O***	**Activity (GJ)**	**Total $CO_{2\,eq}$**	***CO_2***	***CH_4***	***N_2O***		
1990	5 516 169	407.04	*403.12*	*0.001*	*0.013*	1 054	0.087	*0.078*	*0.000004*	*0.000028*	**5 517 223**	**407**
1991	5 765 550	425.44	*421.35*	*0.001*	*0.014*	1 139	0.094	*0.085*	*0.000004*	*0.000030*	**5 766 689**	**426**
1992	5 574 033	411.32	*407.35*	*0.001*	*0.013*	1 065	0.087	*0.079*	*0.000004*	*0.000028*	**5 575 098**	**411**
1993	5 512 762	406.79	*402.87*	*0.001*	*0.013*	1 429	0.117	*0.106*	*0.000005*	*0.000038*	**5 514 191**	**407**
1994	6 993 817	516.04	*511.10*	*0.001*	*0.016*	1 238	0.102	*0.092*	*0.000004*	*0.000033*	**6 995 055**	**516**
1995	7 927 783	584.97	*579.36*	*0.002*	*0.019*	1 246	0.102	*0.092*	*0.000004*	*0.000033*	**7 929 029**	**585**
1996	8 614 215	635.63	*629.52*	*0.002*	*0.020*	1 178	0.097	*0.087*	*0.000004*	*0.000031*	**8 615 393**	**636**
1997	10 305 632	760.42	*753.13*	*0.002*	*0.024*	1 139	0.094	*0.085*	*0.000004*	*0.000030*	**10 306 771**	**761**
1998	12 493 294	921.82	*913.00*	*0.002*	*0.029*	1 140	0.094	*0.085*	*0.000004*	*0.000030*	**12 494 434**	**922**
1999	14 095 591	1 040.09	*1 030.10*	*0.003*	*0.033*	1 252	0.103	*0.093*	*0.000005*	*0.000033*	**14 096 843**	**1 040**
2000	13 434 073	991.33	*981.77*	*0.004*	*0.032*	1 384	0.114	*0.103*	*0.000005*	*0.000036*	**13 435 457**	**991**
2001	14 530 054	1 072.20	*1 061.86*	*0.004*	*0.034*	1 387	0.114	*0.103*	*0.000005*	*0.000036*	**14 531 440**	**1 072**
2002	15 742 564	1 161.66	*1 150.47*	*0.004*	*0.037*	1 462	0.120	*0.108*	*0.000005*	*0.000038*	**15 744 026**	**1 162**
2003	16 399 902	1 210.17	*1 198.51*	*0.004*	*0.039*	1 490	0.122	*0.111*	*0.000005*	*0.000039*	**16 401 392**	**1 210**
2004	17 844 514	1 316.77	*1 304.08*	*0.005*	*0.042*	1 441	0.118	*0.107*	*0.000005*	*0.000037*	**17 845 955**	**1 317**
2005	18 131 067	1 337.97	*1 325.03*	*0.005*	*0.043*	1 933	0.158	*0.143*	*0.000007*	*0.000047*	**18 132 999**	**1 338**
2006	16 967 777	1 252.16	*1 240.02*	*0.005*	*0.040*	2 041	0.166	*0.151*	*0.000007*	*0.000048*	**16 969 818**	**1 252**
2007	18 238 604	1 345.90	*1 332.89*	*0.005*	*0.043*	1 686	0.134	*0.122*	*0.000006*	*0.000040*	**18 240 289**	**1 346**
2008	18 359 132	1 354.79	*1 341.70*	*0.005*	*0.044*	1 835	0.146	*0.133*	*0.000006*	*0.000043*	**18 360 967**	**1 355**
2009	17 588 864	1 297.93	*1 285.40*	*0.005*	*0.042*	1 471	0.117	*0.106*	*0.000005*	*0.000034*	**17 590 335**	**1 298**
2010	17 983 695	1 327.05	*1 314.26*	*0.005*	*0.043*	1 409	0.112	*0.102*	*0.000005*	*0.000033*	**17 985 104**	**1 327**
2011	16 887 889	1 246.22	*1 234.18*	*0.005*	*0.040*	1 734	0.137	*0.125*	*0.000006*	*0.000040*	**16 889 623**	**1 246**
2012	15 581 431	1 149.85	*1 138.71*	*0.005*	*0.037*	1 679	0.133	*0.121*	*0.000005*	*0.000039*	**15 583 110**	**1 150**
2013	15 659 460	1 155.61	*1 144.41*	*0.005*	*0.037*	1 391	0.110	*0.100*	*0.000005*	*0.000032*	**15 660 851**	**1 156**
2014	16 998 090	1 247.45	*1 242.24*	*0.005*	*0.040*	1 553	0.121	*0.110*	*0.000005*	*0.000036*	**16 999 643**	**1 248**
2015	19 161 950	1 400.53	*1 400.37*	*0.005*	*0.045*	1 597	0.123	*0.112*	*0.000005*	*0.000037*	**19 163 548**	**1 401**
Trend 1990-2015	*247.38%*	*244.07%*	*247.38%*	*273.89%*	*247.87%*	*51.56%*	*42.46%*	*43.48%*	*35.27%*	*32.89%*	*247.34%*	*244.03%*

Source: Environment Agency

3.2.2.1 Aviation Bunkers

As there is only one airport for commercial aviation in Luxembourg (located next to Luxembourg City), all commercial flights, either coming to Luxembourg or going out of Luxembourg, are international flights. Non-commercial flights are mainly leisure or urgency (medical, police) flights made with small-sized propeller airplanes or helicopters using aviation gasoline. These flights depart and arrive at the same airport in Luxembourg. Based on communication with an expert of the sole aviation fuel reseller (Luxfuel) and with the aviation authorities about 90% of these non-commercial flights should be considered as domestic flights. The remaining 10% of the light non-commercial aviation flights using aviation gasoline should be considered as international flights, as these flights depart from Luxembourg with an international destination, which could be a small leisure airport in one of the neighbouring countries.[78] Consequently, all kerosene sales (commercial flights) and 10% of the aviation gasoline sales (non-commercial flights) and their related emissions are considered as international flights and, thus, are allocated to international bunkers (see also *1A3a – Domestic aviation*: section **3.2.8.2.2**).

3.2.2.1.1 Activity data

Fuel consumption of jet type kerosene was obtained from the national statistics institute (STATEC) and fuel consumption of aviation gasoline was obtained from the sole vendor of aviation gasoline

[78] This oral communication has been documented internally by the energy expert (ARR 2011, §48).

at the airport (Luxfuel S.A.) (see Table 3-11). Data on the number of landings and take-offs (LTO) has been obtained from national statistics institute (STATEC).

3.2.2.1.2 Methodological issues

The 2006 IPCC Guidelines Tier 2 approach has been applied for flights combusting jet kerosene. This methodology is based on five steps:

- *Estimation of the domestic and international fuel consumption totals for aviation.* In Luxembourg's case this estimation is straight forward as the entire fuel consumption of jet kerosene is considered as international.
- *Estimation of LTO fuel consumption for domestic and international operations.* The LTO fuel consumption of international operations (no domestic operations using jet kerosene) are estimated using a Tier 1 fuel consumption factor from the EMEP/EEA Guidebook 2009 of 825 kg/LTO and representative for an average fleet based on B737-400 short distance flights which is representative of the modern aircrafts operating to and from Luxembourg.
- *Estimation of the cruise fuel consumption for domestic and international aviation.* The cruise fuel consumption was estimated by calculating the difference between the amount of fuel sold and the LTO fuel consumption.
- *Estimation of emissions from LTO and cruise phases for domestic and international aviation.* The emissions of LTO and cruise phases are calculated using emission factors from the EMEP/EEA Guidebook 2009 (please refer to section 3.2.2.1.3 below for more details)
- *Calculation of total emissions = LTO emissions + cruise emissions.*

For non-commercial flights, combusting aviation gasoline, the 2006 IPCC Guidelines Tier 1 approach has been used. As explained above, aviation gasoline fuel consumption was split into 90% domestic non-commercial flights and 10% international non-commercial flights. The respective emissions were estimated using the IPCC default emission factors for aviation gasoline (please refer to section 3.2.2.1.3 below for more details).

3.2.2.1.3 Emission factors

The emission factors, used for calculating emissions from International Bunkers – Aviation, are listed in Table 3-12. Emission factors for jet kerosene are taken from the EMEP-EEA Guidebook on Emission Inventories (EMEP-EEA GB 2009) and correspond to the B737-400 aircraft type which best represents Luxembourg's modern fleet of commercial aircrafts.

Table 3-12 – Emission factors for International Bunkers - Aviation

International Bunkers - Aviation
Emission Factors for 2015

Fuel	Flight Phase	CO_2 EF	CO_2 (unit) type	CH_4 EF	CH_4 (unit) type	N_2O EF	N_2O (unit) type	Source
Jet Kerosene	LTO	*2.600*	*(t/LTO) D*	*0.0001*	*(t/LTO) D*	*0.0001*	*(t/LTO) D*	*EMEP-EEA GB 2013*
	cruise	*3.15*	*(t/t fuel) D*	*0.00*	*(t/t fuel) D*	*0.0001*	*(t/t fuel) D*	
Aviation gasoline	all	*70 000*	*(kg/TJ) D*	*0.50*	*(kg/TJ) D*	*2.00*	*(kg/TJ) D*	*2006 IPCC GL*

Source: Environment Agency

3.2.2.2 Marine Bunkers

As motorised navigation only occurs on the Moselle River, about 20% of the total GHG emissions from shipping are considered as international and are, thus, reported under International Bunkers – Marine.

Activity data and emissions are listed in Table 3-11.

For more details on activity data sources, methodological issues, the split between international and domestic navigation and emission factors used, please refer to Section 3.2.8.5.

3.2.2.3 Multilateral Operations

There are no multilateral operations in Luxembourg, hence notation key NO is used.

3.2.2.4 Category-specific recalculations including changes made in response to the review process

Table 3-13 presents the main revisions and recalculations done since submission 2016v1 relevant to International Bunkers. For the quantitative aspect of these recalculations, plese refer to Chapter 10.

Table 3-13 – Recalculations for International Bunkers

GHG source & sink category	Revisions 2016v1 ➔ 2017v1.2	Type of revision
International Bunkers - Aviation	The CO_2 emission factor for aviation gasoline was corrected from 69300 kg/TJ to 70000 kg/TJ.	CO_2 EF

3.2.2.5 Category-specific QA/QC and verification

Apart from the standard QA/QC procedures, fuel splits between *International Bunker Fuels* and national consumptions were checked to avoid omissions or potential double counting. Jet type kerosene consumption as reported by the national statistics institute in the national energy balance and compared to the inventory is considered to be consistent (see Table 3-14). Also noteworthy is the fact that the national statistical institute does not publish data prior to the year 2000 on its website.

When comparing inventory data with the data as reported by Eurostat, small discrepancies are observed for every year.

Table 3-14 - Discrepancies in International Bunkers – Aviation

Discrepancies in International Bunkers - Aviation between inventory data and international data

Product	Unit	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Aviation gasoline	kt	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aviation gasoline	TJ	44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kerosene type jet fuel	kt	131.800	189.400	321.200	347.000	375.800	391.200	426.200	432.400	405.600	435.500	437.600	420.100	429.300	403.600	371.700	373.700	405.600	458.100
Kerosene type jet fuel	TJ	5 517	7 931	13 449	14 526	15 733	16 380	17 845	18 104	16 983	18 233	18 320	17 587	17 975	16 897	15 561	15 647	16 983	19 182
Kerosene type jet fuel	*TJ/kt or GJ/t*	*41.859*	*41.874*	*41.871*	*41.862*	*41.865*	*41.871*	*41.870*	*41.869*	*41.871*	*41.867*	*41.865*	*41.864*	*41.870*	*41.866*	*41.864*	*41.870*	*41.871*	*41.873*
Source of data	Eurostat																		
Extracted on	30.03.17																		

Product	Unit	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Aviation gasoline	TJ			11.484	9.701	10.353	11.136	8.613	6.308	7.134	9.092	8.570	18.053	15.312	12.050	7.844	8.657	7.961	9.570
Kerosene type jet fuel	TJ			13 433	14 529	15 742	16 399	17 844	18 130	16 967	18 238	18 358	17 588	17 983	16 887	15 581	15 659	16 997	19 161
Source of data	STATEC																		
Extracted on	30.03.16																		

Product	Unit	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Aviation gasoline	kt	0.078	0.277	0.264	0.223	0.238	0.256	0.198	0.145	0.164	0.209	0.197	0.415	0.352	0.277	0.180	0.199	0.183	0.220
Aviation gasoline	TJ	3.410	12.050	11.380	9.612	10.259	11.035	8.535	6.250	7.069	9.009	8.492	17.889	15.173	11.940	7.772	8.578	7.888	9.483
Aviation gasoline	*TJ/kt or GJ/t*	*43.500*	*43.500*	*43.105*	*43.105*	*43.105*	*43.105*	*43.105*	*43.105*	*43.105*	*43.105*	*43.105*	*43.105*	*43.105*	*43.105*	*43.105*	*43.105*	*43.105*	*43.105*
Kerosene type jet fuel	kt	127.963	183.890	311.635	337.061	365.192	380.438	413.955	420.603	393.619	423.100	425.897	408.027	417.187	391.764	361.458	363.269	394.323	444.519
Kerosene type jet fuel	TJ	5 516	7 927	13 433	14 529	15 742	16 399	17 844	18 130	16 967	18 238	18 358	17 588	17 983	16 887	15 581	15 659	16 997	19 161
Kerosene type jet fuel	*TJ/kt or GJ/t*	*43.105*	*43.105*	*43.105*	*43.105*	*43.105*	*43.105*	*43.105*	*43.105*	*43.105*	*43.105*	*43.105*	*43.105*	*43.105*	*43.105*	*43.105*	*43.105*	*43.105*	*43.105*
Source of data	GHG inventory submission 2017v1																		
Extracted on	30.03.2017																		

Difference	Kerosene type	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Inventory/Eurostat	TJ	-1	-4	-16	3	9	19	-1	26	-16	5	38	1	8	-10	20	12	14	-21
Inventory/Statec	TJ	NA	NA	-0	0	0	-0	0	0	-0	-0	0	-0	-0	0	0	0	-0	0

Furthermore, cross-checking between national statistics and data provided by the fuel provider was also undertaken and no discrepancies were found.

3.2.2.6 Planned Improvements

Planned improvements, as listed in Table 3-15, will be explored, based on available resources.

Table 3-15– Planned improvements for International Bunkers

GHG source & sink category	Planned improvement
International Bunkers - Aviation	Analyse LTO data per aircraft type from Eurostat for Luxembourg in order to optimize split between International Bunkers – Aviation and 1A3a – Domestic aviation.

3.2.3 Feedstocks and non-energy use

Non-energy use of fuels is considered in the national energy balance. Below explanations for the reported non-energy use is provided together with information on where CO_2 emissions due to manufacture, use and disposal of carbon containing products are considered.

For the fraction of carbon stored, the IPCC default values are applied.

3.2.3.1 Lubricants

Manufacturing: manufacturing of lubricants does not occur in Luxembourg.

Use: Lubricants are either used in road transportation (motor oil and greases) or in the manufacturing and construction industry (mainly greases). Emissions from lubricants use are reported under category *2D1 – Lubricant Use*. Please refer to section 4.5.1 for more details on the estimation of emissions from lubricant use.

Disposal: incineration of lubricants (waste oil) does not occur in Luxembourg. Waste oil is either recycled or exported.

3.2.3.2 Bitumen

Manufacturing: manufacturing of bitumen does not occur in Luxembourg.

Use: by default the carbon contained in bitumen is considered to be entirely stored in the product, *i.e.* asphalt for road paving.

Disposal: CO_2 emissions from the disposal of bitumen are assumed to be negligible. Recycling is not considered.

3.2.3.3 Coke oven coke

Manufacturing: not occurring. All coke used in the iron and steel industry is imported.

Use: CO_2 emissions from coke used in iron and steel industry are reported under *2.C.1 – Iron and Steel Production*.

Disposal: not applicable.

3.2.3.4 Other bituminous coal

Manufacturing: Manufacturing of electrodes from anthracite used in the electric arc furnaces does not occur in Luxembourg.

Use: Emissions from the use of electrodes in the iron and steel production are considered in category *2.C.1 – Iron and steel production*.

Disposal: not applicable.

3.2.3.5 Other oil products

Manufacturing: not occurring. All products such as white spirits, *etc*. are imported.

Use: CO_2 emissions from solvent and other products use are considered in category *2.D.3. - Non-energy products from fuels and solvent use – Other – Solvent use*.

Disposal: emissions from the disposal of plastics in landfills are considered in *6.A* and emissions from incineration, with energy recovery, of waste plastics are considered in *1 A 1 a*.

3.2.3.6 Category-specific recalculations including changes made in response to the review process

No revisions and recalculations were done since submission 2016v1.

3.2.3.7 Planned improvements

No further improvements are planned.

3.2.4 CO_2 capture from flue gases and subsequent CO_2 storage

CO_2 capture from flue gases and CO_2 storage is not occurring in Luxembourg.

3.2.5 Country specific issues

3.2.5.1 Activity data

As Luxembourg's industrial sector is relatively small compared to larger countries, one has to keep in mind, that, when analysing trends in activity data, relatively large fluctuations may occur in between years simply due to the fact that a facility was temporally switched off for maintenance reasons, or shut-down for good. This may then be reflected by a sharp decrease in the activity data. On the other hand, the bringing into service of a single installation may lead to a sharp increase of activity data in a source category, and consequently also an increase in emissions.

3.2.5.2 Methodological choices

In general, the IPCC methodologies were applied for IPCC category *1-Energy*, except for road transportation and offroad mobile machinery, where detailed calculation model (NEMO and GEORG) were used for non-CO_2 greenhouse gases.

Methodologies used were mostly Tier 1 for solid fuels (except blast furnace gas) and liquid fuels (residual fuel oil, aviation gasoline, kerosene) and Tier 2 for liquid fuels (motor gasoline, diesel oil, gas oil and LPG), gaseous fuel (natural gas), blast furnace gas and waste incineration (Tier 2a, 2006 IPCC Guidelines). For CH_4 and N_2O in road transportation and the off-road sector, the model is considered as a Tier 3 methodology.

Emissions are estimated by multiplying each activity, according to its fuel input, by an emission factor.

Activity data are taken from the energy balance (2000-2015) as compiled by the national statistics institute (STATEC), or obtained directly from plant operators. Energy balance data, covering 1990 to 1999, originates from the Ministry of Economic Affairs (Energy Directorate). Customs and Excise Administration provide data on liquid fuels and biofuels which is used for QA/QC purposes. Activity data obtained through the Emission Trading System (ETS) are used for QA/QC procedures by comparing its data to the data reported by the plant operators.

Net calorific values used for conversion of fuel activity data from physical units into energy units were fixed to national values in agreement with national statistics (STATEC) and the "Office

Commercial du Ravitaillement" (OCRA) of the Ministry of Economic Affairs.[79] These are mostly country-specific values, however, were no such values were available, defaults from the 2006 IPCC Guidelines or the European Directive on Statistics (2006/32/EC) were used (see Table 3-16). For natural gas, please refer to Table 3-17.

Table 3-16 – Fuel Properties for 2015

Fuel Characteristics for 2015 *Country-specific Net Calorific Values and Densities*						
Fuel	**Net calorific value**			**Density**		
	NCV	***Unit***	***Source***	***Density***	***Unit***	***Source***
Anthracite	26.70	GJ/t	*2006 IPCC GL*			
Bituminous Coal & Coking Coal	24.40	GJ/t	*Plant Operator*			
Patent Fuel ("boulets")	28.20	GJ/t	*2006 IPCC GL*			
Brown Coal Briquettes (incl. Lignite dust)	22.20	GJ/t	*Plant Operator*			
Coke Oven Coke	28.50	GJ/t	*EU-2006/32/EC*			
Residual Fuel Oil (low / high sulphur)	40.00	GJ/t	*EU-2006/32/EC*	0.92 / 0.96	kg/l	*Fuel Providers*
Gas Oil	42.49	GJ/t	*Fuel Providers*	0.85	kg/l	*Fuel Providers*
Diesel Oil	42.49	GJ/t	*Fuel Providers*	0.85	kg/l	*Fuel Providers*
Gasoline	43.05	GJ/t	*Fuel Providers*	0.76	kg/l	*Fuel Providers*
Liquefied Petroleum Gas (LPG)	46.00	GJ/t	*EU-2006/32/EC*	0.53	kg/l	*Fuel Providers*
Aviation Gasoline	43.50	GJ/t	*Fuel Provider*	0.71	kg/l	*Fuel Provider*
Jet Kerosene	43.11	GJ/t	*Fuel Provider*			
Other Kerosene	43.80	GJ/t	*2006 IPCC GL*			
Wood	7.15	GJ/m^3	*Statec*	0.69	t/m^3	*Statec*
Pellets	11.00	GJ/m^3	*Statec*	0.65	t/m^3	*Statec*
Wood chips	7.81	GJ/m^3	*Statec*	0.69	t/m^3	*Statec*
Biogaz	0.02	GJ/m^3	*Statec*			
Biodiesel (pure)	39.76	GJ/t	*Fuel Providers*			
Lubricants	40.20	GJ/t	*2006 IPCC GL*			
Bitumen	40.20	GJ/t	*2006 IPCC GL*			

Source: Environment Agency

Emission factors are defaults from 2006 IPCC Guidelines for solid (except blast furnace gas) and some liquid fuels and country-specific for natural gas, motor gasoline, gas/diesel oil, and LPG.

3.2.5.3 Country specific emission factors

Blast Furnace Gas

A country-specific CO_2 emission factor for the combustion of blast furnace gas was determined based on emission measurement data and on the CO and CO_2 contents of blast furnace gas produced in Luxembourg's blast furnaces in 1990.[80] As no further measurements were available until the closure of the blast furnaces in 1997, the same emission factor, *i.e.* 257'181 kg CO_2/TJ, was used for the years 1990 to 1997.

79 ARR 2010, § 21

80 TÜV Rheinland, 1990, Bericht: 934/651014.

Similarly, a country-specific CO_2 emission factor for blast furnace gas lost in distribution or flared was determined: 245'323 kg CO_2/TJ.

Natural Gas

In Luxembourg, one operator, CREOS S.A. (formerly SOTEG S.A.)[81], operates the national natural gas network (Figure 3-5). There are four entry points, from where natural gas is imported: two with Belgium (Braz and Pétange) with a capacity of 0.16 and 0.06 Mio Nm^3/h, respectively, one with Germany (Remich) with a capacity of 0.19 Mio Nm^3/h and one with France (Esch/Alzette) with a capacity of 0.02 Mio Nm^3/h.

For the calculation of the country-specific CO_2 emission factor for natural gas, the operator provides the following parameters for each entry point and for each month of a given year:

- chemical composition (methane, ethane, propane, i-butane, n-butane, i-pentane, n-pentane, hexane & higher, CO_2 and N_2) expressed in mol%;
- physical properties: density (kg/Nm^3) and gross calorific value (GCV: MJ/Nm^3);
- monthly import/consumption (Mio Nm_3). [82]

The monthly consumption is converted into energy units (TJ) using the respective NCV, which is calculated by multiplying the GCV with a conversion factor of 0.90 [83].

From the monthly chemical composition, a monthly average "molecular" weight for natural gas (g/mol), "molecular" density (mol/Nm^3) and monthly carbon content (mol C/ mol Natural Gas) are derived for each entry point. The monthly carbon content is then converted into a monthly emission factor (g CO_2/MJ) assuming full oxidation of carbon to carbon dioxide. By multiplying the monthly emission factor with the respective monthly natural gas consumption, a monthly CO_2 emission is obtained. Finally, by dividing the yearly national emissions (sum of the monthly emissions of all 4 entry points) by the yearly national consumption (sum of the monthly consumptions of all 4 entry points), the country-specific emission factor for the respective year is obtained.

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81 http://www.creos.lu

82 Nm^3 is defined at a pressure of 1035 mbar and 0 degree Celsius.

83 IEA Energy Statistics Manual, 2005, Table A3.12, p.183

Figure 3-5 - Natural gas network

Source: Creos

Country-specific NCVs and emission factors have, thus, been obtained for the years 1991, 1995, 2000, 2005-2015 (Table 3-17). For the years in-between, the values have been interpolated.

Table 3-17 - Country-specific NCV and Emission Factors for Natural Gas: 1990-2015

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
EF (t CO_2/TJ)	57.76	57.74	57.85	57.89	57.94	57.93	57.55	57.20	56.86	56.52
NCV (MJ/Nm^3)	36.58	36.67	36.62	36.64	36.66	36.75	36.85	36.92	36.99	37.06
Year	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
EF (t CO_2/TJ)	56.22	56.26	56.40	56.53	56.67	56.91	57.01	56.79	56.66	57.06
NCV (MJ/Nm^3)	37.10	37.01	36.96	36.91	36.86	36.85	36.72	36.64	36.48	36.72
Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**				
EF (t CO_2/TJ)	56.71	56.99	56.79	56.68	56.76	56.76				
NCV (MJ/Nm^3)	36.73	36.56	36.38	36.19	36.30	36.81				

Source: Environment Agency

Motor Gasoline, Gas/Diesel Oil, Liquefied Petroleum Gas

In Luxembourg, refined oil products such as motor gasoline, gasoil, diesel oil and liquefied petroleum gas (LPG) are exclusively imported from the neighbouring countries Belgium, the Netherlands and Germany, and to a minor extent from France. As the Luxembourgish association of mineral oil companies (Groupement Pétrolier Luxembourgeois a.s.b.l.) was not able to provide country-specific carbon contents of the before-mentioned fuels to the Environment Agency, country-specific emission factors for motor gasoline, gas/diesel oil and LPG were derived from the emission factors of the corresponding import countries in relation with the yearly quantities imported.[84] Thus, country-specific emission factors have been obtained for the entire time-series (Table 3-18).

Table 3-18 - Country-specific Emission Factors for Gas/Diesel Oil, Motor Gasoline and LPG: 1990-2015 (tCO_2/TJ)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Gas/Diesel Oil	73.87	73.88	73.91	73.87	73.85	73.84	73.85	73.85	73.86	73.85
Motor Gasoline	71.01	71.05	71.28	71.26	71.22	71.18	71.14	71.10	71.11	71.09
LPG	65.04	65.04	64.97	64.93	64.93	64.93	64.93	64.93	64.95	65.26
Year	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Gas/Diesel Oil	73.83	73.82	73.82	73.84	73.87	73.88	73.88	73.86	73.87	73.87
Motor Gasoline	71.08	71.13	71.12	71.08	71.07	71.08	71.14	71.12	71.27	71.10
LPG	64.94	64.94	64.96	64.98	64.95	64.95	64.96	64.93	64.93	64.96
Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**				
Gas/Diesel Oil	73.87	73.86	73.85	73.86	73.87	73.86				
Motor Gasoline	71.04	71.05	70.99	71.37	71.49	71.55				
LPG	64.93	64.93	64.93	64.93	64.93	64.93				

Source: Environment Agency

In submission 2012v1.2, Luxembourg's country specific emission factor was revised in accordance with a technical review recommendation during the 2012 technical review of the greenhouse gas emission inventory of Luxembourg to support the determination of annual emission allocations under the European Decision 406/2009/EC. Indeed, the TERT (Technical Expert Review Team) observed that:

"*Luxembourg is using the CO_2 EF value for gasoline used by Belgium that in turn uses the IPCC default value. CO_2 from road transportation is a key category, however the 2000 IPCC Good Practice Guidance (GPG) states in this respect: 'For traded fuels in common circulation, it is good practice to obtain the carbon content of the fuel and net calorific values from fuel suppliers, and use local values wherever possible. If these data are not available, default values can be used.'*

The TERT also notes that the implied EF is at the low end as compared with other Member States (which have country specific data), which could indicate an underestimation of emissions. The TERT also notes that local or country-specific data should be available in Luxembourg and that therefore the use of the default value is not in line with good practice."

In response to this observation and because no data on the carbon content is available in Luxembourg, Luxembourg decided to revise its CO_2 emission factor for motor gasoline, based on the CO_2 emission factor of the two other neighbouring countries from which motor gasoline is imported. Indeed, as the Netherlands and Germany both use a CO_2 EF of 72 tCO_2/TJ, Luxembourg decided to apply the same EF as a country-specific EF for the entire time series, to which the TERT agreed.

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84 ARR 2009, § 48

Then, during the UNFCCC centralised review in September 2016, the ERT recommended that Luxembourg switches back to the previous approach where a country-specific CO_2 emission factor for gasoline is determined according to the quantities of gasoline imported from the different countries and the respective emission factors used by these countries. This approach is used in this submission for the entire time-series, in all sub-categories to which gasoline is allocated (1A2gvii, 1A3b, 1A3d, 1A4b).

3.2.6 Energy Industries (1.A.1): Public Electricity and Heat Production (1.A.1.a)

3.2.6.1 Source category description

This section describes GHG emissions resulting from fuel combustion activities in energy industries, which, in Luxembourg, only originate from public electricity and heat production plants. There is no manufacturing of solid fuels, nor petroleum refining in Luxembourg. Hence, IPCC category *1A1 – Energy Industries* equals IPCC sub-category *1A1a – Public Electricity and Heat Production*.

In this category CO_2, CH_4 and N_2O emissions from combustion activities for electricity and heat production are reported, as well as CO_2, CH_4 and N_2O emissions from municipal waste incineration. In Luxembourg, municipal waste is combusted with energy recovery at the sole waste incineration plant (SIDOR) where recovered heat and electricity are distributed to the urban district network. Therefore, the emissions are reported under fuel combustion emissions.

In 2015, this source category was responsible for 5.18% of GHG emissions from fuel combustion activities (0.35% in 1990) and represented 4.25% of the national total GHG emissions in CO_2e, excluding LULUCF (0.28% in 1990). Table 3-19 summarizes GHG emissions for category *1.A.1. - Energy Industries*. Compared to 2014, GHG emissions have decreased by 31.6%. Since 2013, the electricity production level by the Twinerg gas turbine had already been at a relatively low level, due to relatively low electricity prices, and the plant was finally shut down in 2016.

Regarding CO_2 emissions, *1A1a - Public electricity and heat production* is a key category in 2015 for gaseous fuels and other fuels (MSW): see Table 3-6 in Section 3.2.

Table 3-19 – GHG emission trends in CO_2e category *1A1 –Energy Industries*: 1990-2015

1A1 - Energy Industries

GHG emissions by source & sink category (Gg)

Year	1A1a - Public Electricity & Heat Production				1A1b - Petroleum Refining				1A1c - Manuf. of Solid Fuels & Other Energy Ind.			
	Total $CO_{2\,eq}$	*CO_2 (excl. biomass)*	*CH_4 (incl. biomass)*	*N_2O (incl. biomass)*	Total $CO_{2\,eq}$	*CO_2 (excl. biomass)*	*CH_4 (incl. biomass)*	*N_2O (incl. biomass)*	Total $CO_{2\,eq}$	*CO_2 (excl. biomass)*	*CH_4 (incl. biomass)*	*N_2O (incl. biomass)*
1990	35.64	*33.29*	*0.036*	*0.005*	NO	*NO*	*NO*	*NO*	NO	*NO*	*NO*	*NO*
1991	37.29	*34.83*	*0.038*	*0.005*	NO	*NO*	*NO*	*NO*	NO	*NO*	*NO*	*NO*
1992	37.19	*34.73*	*0.038*	*0.005*	NO	*NO*	*NO*	*NO*	NO	*NO*	*NO*	*NO*
1993	35.38	*33.04*	*0.036*	*0.005*	NO	*NO*	*NO*	*NO*	NO	*NO*	*NO*	*NO*
1994	34.61	*32.32*	*0.035*	*0.005*	NO	*NO*	*NO*	*NO*	NO	*NO*	*NO*	*NO*
1995	93.54	*91.29*	*0.035*	*0.005*	NO	*NO*	*NO*	*NO*	NO	*NO*	*NO*	*NO*
1996	82.35	*80.61*	*0.027*	*0.004*	NO	*NO*	*NO*	*NO*	NO	*NO*	*NO*	*NO*
1997	89.72	*87.66*	*0.032*	*0.004*	NO	*NO*	*NO*	*NO*	NO	*NO*	*NO*	*NO*
1998	155.93	*153.38*	*0.040*	*0.005*	NO	*NO*	*NO*	*NO*	NO	*NO*	*NO*	*NO*
1999	173.46	*170.54*	*0.045*	*0.006*	NO	*NO*	*NO*	*NO*	NO	*NO*	*NO*	*NO*
2000	120.17	*117.37*	*0.043*	*0.006*	NO	*NO*	*NO*	*NO*	NO	*NO*	*NO*	*NO*
2001	282.26	*279.33*	*0.046*	*0.006*	NO	*NO*	*NO*	*NO*	NO	*NO*	*NO*	*NO*
2002	1 029.32	*1 025.62*	*0.060*	*0.007*	NO	*NO*	*NO*	*NO*	NO	*NO*	*NO*	*NO*
2003	1 036.71	*1 032.90*	*0.061*	*0.008*	NO	*NO*	*NO*	*NO*	NO	*NO*	*NO*	*NO*
2004	1 257.41	*1 253.26*	*0.067*	*0.008*	NO	*NO*	*NO*	*NO*	NO	*NO*	*NO*	*NO*
2005	1 243.19	*1 239.18*	*0.065*	*0.008*	NO	*NO*	*NO*	*NO*	NO	*NO*	*NO*	*NO*
2006	1 305.28	*1 301.09*	*0.068*	*0.008*	NO	*NO*	*NO*	*NO*	NO	*NO*	*NO*	*NO*
2007	1 181.71	*1 177.54*	*0.067*	*0.008*	NO	*NO*	*NO*	*NO*	NO	*NO*	*NO*	*NO*
2008	996.00	*991.94*	*0.065*	*0.008*	NO	*NO*	*NO*	*NO*	NO	*NO*	*NO*	*NO*
2009	1 190.78	*1 186.67*	*0.067*	*0.008*	NO	*NO*	*NO*	*NO*	NO	*NO*	*NO*	*NO*
2010	1 205.97	*1 202.05*	*0.064*	*0.008*	NO	*NO*	*NO*	*NO*	NO	*NO*	*NO*	*NO*
2011	1 004.16	*1 000.20*	*0.064*	*0.008*	NO	*NO*	*NO*	*NO*	NO	*NO*	*NO*	*NO*
2012	1 042.72	*1 038.72*	*0.064*	*0.008*	NO	*NO*	*NO*	*NO*	NO	*NO*	*NO*	*NO*
2013	685.89	*682.30*	*0.057*	*0.007*	NO	*NO*	*NO*	*NO*	NO	*NO*	*NO*	*NO*
2014	668.52	*664.65*	*0.061*	*0.008*	NO	*NO*	*NO*	*NO*	NO	*NO*	*NO*	*NO*
2015	457.22	*453.05*	*0.065*	*0.008*	NO	*NO*	*NO*	*NO*	NO	*NO*	*NO*	*NO*
Trend 1990-2015	*1182.74%*	*1261.01%*	*79.81%*	*75.14%*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Trend 2014-2015	*-31.61%*	*-31.84%*	*6.49%*	*8.44%*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*

Source: Environment Agency.

Notes: CH_4 emissions are converted in CO_2e by multiplying the emissions by 25, *i.e.* the global warming potential (*GWP*) value for methane based on the effects of GHG over a 100-year time horizon.

N_2O emissions are converted in CO_2e by multiplying the emissions by 298, *i.e.* the global warming potential (*GWP*) value for nitrous oxide based on the effects of GHG over a 100-year time horizon.

3.2.6.2 Methodological issues

3.2.6.2.1 Activity data

Activity data of the various installations considered in *1A1a*:

- combined heat and power (*CHP*) installations, which have appeared at the beginning of the 1990s. Those installations generally use combustion engines, and they are operated with natural gas and/or gasoil and to a smaller extent with biogas or wood & wood wastes. The activity rates are based on information received from the operators and on the energy balance as compiled by the national statistics institute (STATEC).
- a CHP gas turbine (350MW) running on natural gas and operated since 2002 by Twinerg S.A. Since heat was not recovered from 2002 to 2010, this unit was counted as a thermal power plant and not as a cogeneration plant in official statistics. Since 2011 however, heat recovery is done and the installation is considered as a cogeneration plant. However, this classification change has no impact on the GHG emission estimates since it is the fuel(s) used and the technology that matter. There are several smaller CHP gas turbines, which are operated on industrial sites, but which produce heat and electricity mainly for the respective industries. Emissions related to these are accounted for in *1A2-Manufacturing Industries and Construction*, as these installations are considered as autoproducers.
- one waste incinerator (SIDOR) is fed with natural gas and/or gas oil and high calorific municipal solid waste (MSW). MSW incinerated is composed of paper/cardboard, textiles, food waste, wood, garden & park waste, nappies, rubber & leather, plastics, multilayer composite material, metal, glass, other inert waste. The MSW is untreated and partially split into a high calorific fraction which is incinerated and a low calorific fraction which is deposited on land[85]). No industrial and hazardous wastes are incinerated because they are exported. Activity data on municipal waste composition are taken from the following studies and for the years in-between a linear interpolation was carried out. For 1990-2001, the composition is calculated based on:
    - Waste Division of the Environment Agency, "Restabfallanalyse 2001 im SIDOR", Luxembourg, 2002;
    - Waste Division of the Environment Agency, "Restabfallanalyse 1992/1994", Luxembourg, 2002.

  For 2002-2015, MSW fractions are calculated similarly based on the following waste composition analysis:
    - Waste Division of the Environment Agency, "Restabfallanalyse 2013/14 im Großherzogtum Luxemburg, Band 1: Kompendium", Luxembourg, 2016;
    - Waste Division of the Environment Agency, "Restabfallanalyse 2009/10 im Großherzogtum Luxemburg, Band 1: Kompendium", Luxembourg, 2010;
    - Waste Division of the Environment Agency, "Restabfallanalyse 2004/05 im Großherzogtum Luxemburg, Band 1: Kompendium", Luxembourg, 2005;

85 For the different waste treatment schemes, see Chapter 8 on waste.

However, one part of the waste incinerated originates from a pre-treatment plant (MBA Fridhaff), where a high calorific fraction is sorted out for incineration. The rest is disposed of on landfill sites. The composition of the high calorific faction is calculated based on the following studies :

- Air & Noise Division of the Environment Agency, " Estimation of emitted greenhouse gases by the selected high calorific fraction from SIDEC being incinerated ", Luxembourg, 2010
- Air & Noise Division of the Environment Agency, "Estimation of emitted greenhouse gases by the selected high calorific fraction from SIDEC being incinerated", Luxembourg, 2016

Table 3–20 gives an overview of the energy consumption by fuel type in *1A1a – Public Electricity and Heat Production*.

Table 3-20 - Activity data for IPCC sub-category 1A1a – Public Electricity and Heat Production: 1990-2015

1A1a - Public Electricity & Heat Production *Activity Data by fuel type (GJ)*					
Year	Activity Total (incl. biomass)	Liquid *Gas Oil*	Gaseous *Natural Gas*	Biomass *Biogas, Wood & MSW (biogenic fraction)*	Other *MSW (fossil fraction)*
1990	1 213 293	*NO*	*NO*	*877 003*	*336 290*
1991	1 269 447	*NO*	*NO*	*917 593*	*351 854*
1992	1 282 780	*NO*	*NO*	*931 942*	*350 838*
1993	1 221 173	*NO*	*NO*	*887 411*	*333 762*
1994	1 195 144	*NO*	*NO*	*868 596*	*326 548*
1995	2 187 248	*NO*	*1 043 100*	*832 290*	*311 859*
1996	1 874 986	*900*	*984 600*	*648 213*	*241 274*
1997	2 078 487	*18 919*	*1 013 400*	*760 358*	*285 810*
1998	3 011 697	*30 783*	*1 709 100*	*687 092*	*584 722*
1999	3 367 501	*31 593*	*1 883 700*	*782 767*	*669 441*
2000	2 424 540	*76 176*	*920 854*	*777 172*	*650 338*
2001	5 312 708	*79 489*	*3 808 343*	*782 746*	*642 130*
2002	18 551 830	*67 169*	*17 031 071*	*800 879*	*652 711*
2003	18 695 356	*62 283*	*17 102 526*	*899 751*	*630 796*
2004	22 540 527	*66 616*	*20 850 220*	*931 279*	*692 412*
2005	22 279 475	*43 250*	*20 647 091*	*962 615*	*626 519*
2006	23 339 640	*39 936*	*21 624 432*	*999 055*	*676 217*
2007	21 289 587	*39 171*	*19 508 383*	*1 052 385*	*689 647*
2008	18 074 720	*65 639*	*16 205 838*	*1 088 938*	*714 304*
2009	21 392 399	*86 882*	*19 534 163*	*1 081 297*	*690 058*
2010	21 861 285	*33 053*	*20 082 942*	*1 107 901*	*637 389*
2011	18 257 151	*33 698*	*16 344 441*	*1 181 148*	*697 864*
2012	19 003 659	*28 975*	*17 071 478*	*1 197 411*	*705 795*
2013	12 746 889	*21 965*	*10 853 489*	*1 179 447*	*691 988*
2014	12 503 025	*19 671*	*10 369 609*	*1 293 481*	*820 265*
2015	8 902 019	*22 047*	*6 492 850*	*1 474 491*	*912 632*
Trend 1990-2015	*NA*	*NA*	*NA*	*68.13%*	*171.38%*
Trend 2014-2015	*-28.80%*	*12.08%*	*-37.39%*	*13.99%*	*11.26%*

Source: Environment Agency.

3.2.6.2.2 Methodological choices

The 2006 IPCC Guidelines Tier 1 approach has been applied for biomass burning (biogas & wood and wood wastes), except for the biogenic fraction of MSW. For natural gas and gasoil, the methodological approach is classified as Tier 2 methodology as country-specific emission factors were used.

For waste incineration, the IPCC methodology Tier 2a (2006 IPCC Guidelines) has been applied. For MSW, it is good practice to calculate CO_2 emissions on the basis of waste fractions (such as paper, wood, plastics) in the waste incinerated, as the following equation shows:

$$CO_2 \; emissions = MSW \bullet \sum_j (WF_j \bullet dm_j \bullet CF_j \bullet FCF_j \bullet OF_j) \bullet \frac{44}{12}$$

with:

CO_2 emissions	= CO_2 emissions in inventory year (Gg/yr)
MSW	= total amount of municipal solid waste as wet weight incinerated or open-burned (Gg/yr)
WF_j	= fraction of waste type/material of component j in the MSW (as wet weight incinerated or open-burned)
dm_j	= dry matter content in the component j of the MSW incinerated or open-burned (fraction)
CF_j	= fraction of carbon in the dry matter (*i.e.*, carbon content) of component j
FCF_j	= fraction of fossil carbon in the total carbon of component j
OF_j	= oxidation factor (fraction)
44/12	= molecular weight ratio M_{CO2}(g/mol)/M_C(g/mol)

with:

$$\sum_j WF_j = 1$$

j = component of the MSW incinerated such as paper/cardboard, textiles, food waste, wood, garden (yard) and park waste, disposable nappies, rubber and leather, plastics, metal, glass, other inert waste.

IPCC default values for dm_j, CF_j, FCF_j and OF_j were taken.[86]

Reported CO_2 emissions of waste incineration are only CO_2 emissions from fossil MSW. However, the activity data includes both biogenic and fossil MSW fractions. This means that biogenic CO_2 emissions are reported under *Memo Items*.

Calorific values used for conversion of fuel activity data from tonnes into GJ are country-specific and derive from the Waste Division of the Environment Agency (see Table 3-21).[87]

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86 2006 IPCC Guidelines, Vol. 5, Chap. 2, Tab. 2.4, p2.14

87 *Restabfallanalyse 2004/05 im Großherzogtum Luxemburg, Band 1: Kompendium*, Luxembourg, 2005.

Table 3-21 – Calorific values for MSW components

MSW component	Heating value [GJ/t]	MSW component	Heating value [GJ/t]
Paper/cardboard	13	Rubber and Leather	5
Textiles	13	Multilayer composite material	15
Food waste	5	Plastics	30
Wood	5	Metal	0
Garden and Park waste	5	Glass	0
Nappies	10	Other, Inert waste	7

CH_4 emissions were estimated using 2006 IPCC Guidelines Tier 1 methodology. CH_4 emissions from incineration of waste are a result of incomplete combustion. Important factors affecting the emissions are temperature, residence time, and air ratio (*i.e.*, air volume in relation to the waste amount). CH_4 emissions are calculated according to the following equation:

$$CH_4\ Emissions = Fuel\ Consumption_{MSW} \bullet Emission\ Factor_{MSW}$$

with:

CH_4 Emissions = CH_4 emissions (kg GHG)

Fuel $Consumption_{MSW}$ = amount of incinerated MSW (TJ)

Emission $Factor_{MSW}$ = emission factor (kg gas/TJ)

The CH_4 emissions are relative to total MSW (biogenic + fossil).

Nitrous oxide is emitted in combustion processes at relatively low combustion temperatures between 500 and 950°C. Other important factors affecting the emissions are the type of air pollution control device, nitrogen type and content of the waste and the fraction of excess air. The N_2O emissions are calculated according to the following equation:

$$N_2O\ emission = \sum_j (IW_j \bullet EF_j) \bullet 10^{-6}$$

with:

N_2O Emissions = N_2O emissions in inventory year (Gg/yr)

IW_i = amount of incinerated waste of type i (Gg/yr)

EF_i = N_2O emission factor (kg N2O /Gg of waste) for waste of type i

10^{-6} = conversion from kilogram to gigagram

i = category or type of waste incinerated (MSW)

The N_2O emissions are relative to total MSW (biogenic + fossil).

3.2.6.2.3 Emission factors

Default emission factors are derived from IPCC 2006 Guidelines (Table 3-22). Country-specific emission factors were determined by the Environment Agency and were calculated from specific data accessible to the Environment Agency (see section 3.2.5.3).

For MSW, CO_2 emissions were not calculated using an emission factor, but instead, the calculation is based on the carbon content of the waste. CO_2 emissions are calculated, as described in section 3.2.6.2.2, by applying the default values listed in Table 3-13 of the 2006 IPCC Guidelines for:

- dry matter content in % of wet weight;
- DOC content in % of wet waste;
- DOC content in % of dry waste;
- total carbon content in % of dry weight;
- fossil carbon fraction in % of total carbon.

For CO_2, implied emission factors (IEFs) for the different waste components were then calculated by dividing the calculated emission by the energy content of the MSW waste fraction.

For CH_4, it is good practice to apply the CH_4 emission factors provided in Volume 2, Chapter 2 of the 2006 IPCC Guidelines. The CH_4 default emission factor of 30 kg CH_4/TJ is applied.

For N_2O, the default emission factor of 4.0 kg N_2O/TJ is applied. However, this emission factor might be revised in one of the next submissions, as the 2006 IPCC guidelines recommend to use an EF of 50 g N_2O/t MSW on a wet basis (Vol.5, Chap.5, Table 5.6).

Table 3-22 gives an overview of the different emission factors used for 2015.

Table 3-22 – Emission factors for IPCC sub-category 1A1a – Public Electricity and Heat Production

1A1a - Public Electricity & Heat Production
Emission Factors for 2015 (kg/TJ)

Fuel	Fuel Type	CO_2		CH_4		N_2O		Source
		EF	*type*	*EF*	*type*	*EF*	*type*	
Gas Oil	liquid	*73 858*	*CS*	*3.00*	*D*	*0.60*	*D*	*AEV; 2006 IPCC GL*
Natural Gas	gaseous	*56 760*	*CS*	*1.00*	*D*	*0.10*	*D*	*AEV, 2006 IPCC GL*
Biogas	biomass	*54 600*	*D*	*1.00*	*D*	*0.10*	*D*	*2006 IPCC GL*
Wood & wood wastes	biomass	*112 000*	*D*	*30.00*	*D*	*4.00*	*D*	*2006 IPCC GL*
MSW (biogenic	biomass	*90 817*	*IEF*	*30.00*	*D*	*4.00*	*D*	*AEV, 2006 IPCC GL*
MSW (fossil)	other	*90 149*	*IEF*	*30.00*	*D*	*4.00*	*D*	*AEV, 2006 IPCC GL*

Source: Environment Agency.
Notes: IEFs and CS EFs were determined by the Environment Agency.

Table 3-23 gives an overview of the evolution of the implied emission factors per fuel type.

Table 3-23 – Implied emission factors for IPCC sub-category 1A1a – Public Electricity and Heat Production

1A1a - Public Electricity & Heat Production *Implied Emission Factors (kg/TJ)*												
Year	Liquid *Gas Oil*			Gaseous *Natural Gas*			Biomass *Biogas, Wood & MSW (biogenic fraction)*			Other *MSW (fossil fraction)*		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
1990	NO	NO	NO	NO	NO	NO	98 984	30.00	4.00	98 984	30.00	4.00
1991	NO	NO	NO	NO	NO	NO	98 984	30.00	4.00	98 984	30.00	4.00
1992	NO	NO	NO	NO	NO	NO	98 175	29.47	3.93	98 984	30.00	4.00
1993	NO	NO	NO	NO	NO	NO	98 134	29.44	3.93	98 984	30.00	4.00
1994	NO	NO	NO	NO	NO	NO	98 116	29.43	3.92	98 984	30.00	4.00
1995	NO	NO	NO	57 929	1.00	0.10	97 971	29.34	3.91	98 984	30.00	4.00
1996	73 851	3.00	0.60	57 546	1.00	0.10	97 684	29.15	3.89	98 984	30.00	4.00
1997	73 851	3.00	0.60	57 205	1.00	0.10	98 109	29.43	3.92	98 984	30.00	4.00
1998	73 857	3.00	0.60	56 863	1.00	0.10	91 695	29.60	3.95	92 215	30.00	4.00
1999	73 855	3.00	0.60	56 522	1.00	0.10	92 099	29.85	3.98	92 215	30.00	4.00
2000	73 827	3.00	0.60	56 221	1.00	0.10	91 427	29.30	3.91	92 215	30.00	4.00
2001	73 825	3.00	0.60	56 258	1.00	0.10	90 708	28.75	3.83	92 215	30.00	4.00
2002	73 825	3.00	0.60	56 396	1.00	0.10	90 625	28.64	3.82	92 202	30.00	4.00
2003	73 844	3.00	0.60	56 533	1.00	0.10	94 699	27.98	3.73	97 395	30.00	4.00
2004	73 870	3.00	0.60	56 671	1.00	0.10	92 615	27.38	3.65	96 373	30.00	4.00
2005	73 882	3.00	0.60	56 910	1.00	0.10	92 940	26.61	3.54	97 297	30.00	4.00
2006	73 876	3.00	0.60	57 008	1.00	0.10	91 519	26.08	3.47	96 654	30.00	4.00
2007	73 862	3.00	0.60	56 793	1.00	0.10	91 331	25.83	3.44	96 725	30.00	4.00
2008	73 874	3.00	0.60	56 665	1.00	0.10	90 154	25.17	3.35	96 301	30.00	4.00
2009	73 867	3.00	0.60	57 056	1.00	0.10	88 010	24.08	3.20	95 220	30.00	4.00
2010	73 867	3.00	0.60	56 712	1.00	0.10	85 021	22.00	2.92	95 184	30.00	4.00
2011	73 859	3.00	0.60	56 988	1.00	0.10	85 395	22.30	2.96	94 953	30.00	4.00
2012	73 852	3.00	0.60	56 793	1.00	0.10	84 866	21.79	2.90	94 995	30.00	4.00
2013	73 862	3.00	0.60	56 680	1.00	0.10	84 407	21.60	2.87	94 649	30.00	4.00
2014	73 874	3.00	0.60	56 756	1.00	0.10	80 991	20.43	2.71	91 019	30.00	4.00
2015	73 858	3.00	0.60	56 760	1.00	0.10	82 440	21.37	2.84	90 817	30.00	4.00

Source: Environment Agency.

The unique trend of the CO_2 implied emission factor for other fuels, which is composed solely of the fossil fraction of incinerated MSW and as reported in Table 3-23, is due to the varying composition of the fossil fraction over time. Indeed, as explained in section 3.2.6.2.1, the composition of the waste fraction is based on several waste analyses. The fractions determined in the study of 1992/1994 were applied to the years 1990-1997; the fractions determined in the study of 2001 were applied to the period 1998-2002; the fractions of the study of 2004/2005 were applied to the years 2003-2008 and the fractions of the study 2009/2010 were applied to the year 2009 and following. In addition, since 2002, a high calorific fraction of MSW, composed of mainly plastics, textiles, rubbers and other waste, also influences the composition of incinerated waste as this high calorific fraction is co-incinerated with MSW. Hence, the changes in the CO_2 IEF between specific years correspond to the breaks in the composition of incinerated waste.

3.2.6.3 Uncertainties and time-series consistency

The uncertainties for activity data and emission factors used for IPCC category *1A1 – Energy Industries* are presented in Table 3-24.

Table 3-24: uncertainties for activity data and emission factors used for IPCC category 1A1 – Energy Industries.

IPCC category/Group	Gas	Activity data uncertainty (%)	Emission factor uncertainty (%)
1A1 - Gaseous Fuels	CO2	2%	1%
1A1 - Gaseous Fuels	CH4	2%	50%
1A1 - Gaseous Fuels	N2O	2%	50%
1A1 - Liquid Fuels	CO2	2%	1%

1A1 - Liquid Fuels	CH4	2%	50%
1A1 - Liquid Fuels	N2O	2%	50%
1A1 - Other Fuels	CO2	8%	20%
1A1 - Other Fuels	CH4	8%	50%
1A1 - Other Fuels	N2O	8%	50%
1A1 - Biomass	CH4	7%	50%
1A1 - Biomass	N2O	7%	60%

The time-series are considered to be consistent with the data reported in the energy balance.

The annual fluctuations in fuel consumption, especially for natural gas, and the resulting fluctuations of GHG emissions, are explained by the fluctuations of electricity and heat production levels of the plants covering the sector. Indeed, a sharp increase in the natural gas consumption was observed in 2002, with the operational start of a 350 MW gas turbine (Twinerg). In the following, maintenance stops (2009, 2011) of the 350 MW gas turbine, some times during several months, greatly influence the energy demand of this category. Since 2013, the electricity production level by the Twinerg gas turbine had been at a relatively low level (due to relatively low electricity prices), and the plant was finally shut down in 2016.

In addition, rotation of the gasoil stocks (used as emergency fuel) can cause fluctuations in the GHG emissions. This was the case in 2008-2009. The dip of fossil MSW incineration in 1996 was due to a fire in the incineration plant, followed by a shut-down for several months.

3.2.6.4 Source-specific QA/QC and verification

Activity data for large facilities that are under the European Union Emission Trading Scheme (EU-ETS) is cross-checked from two sources: reports obtained directly from the operator under its operational permit obligations and the EU-ETS registry operator. Both are hosted at the Environment Agency. A list with the large energy consuming facilities along with their respective fuel consumption has been compiled and enables the Single National Entity to quickly cross-check this data with the EU-ETS data. Thus, completeness can be checked on a more systematic basis.

Additionally, cross checks with other relevant sectors, mainly *5 – Waste*, are performed to avoid double counting.

Finally, consistency and completeness checks are performed using the tools embedded in CRF Reporter.

3.2.6.5 Category-specific recalculations including changes made in response to the review process

Table 3-25 presents the main revisions and recalculations relevant to category *1A1a - Public Electricity and Heat Production* done since the last submission. For the quantitative aspect of these recalculations, please refer to Chapter 10.

Table 3-25 – Recalculations done since submission 2016v1

GHG source & sink category	Revisions 2016v1 ➔ 2017v1.2	Type of revision
1A1a	Natural gas consumption in 1A1a for the year 2014 was revised in the national energy balance.	Updated AD
1A1a	Two transcription errors affecting the emissions from MSW in 1.A.1.a – Public Electricity and Heat Production in 1991 and 2013 have been corrected.	updated AD
1A1a	An adjustment of the total MSW in the Grand-Duchy (as explained in more detail in section 0) impacts the emissions for the timeseries 2001-2014, as the calorific fraction is deducted from SIDOR's MSW to avoid double counting.	updated AD
1A1a	waste incineration with energy recovery: implemented new waste composition analysis from 2013/14	updated AD

3.2.6.6 Category-specific planned improvements including those in response to the review process

Table 3-26 presents the main revisions and recalculations relevant to category *1A1a - Public Electricity and Heat Production* done since the last submission.

Table 3-26 – Planned improvements for category *1.A.1. – Energy Industries*

GHG source & sink category	Planned improvement
1A1a - Public Electricity and Heat Production	No planned improvements

3.2.7 Manufacturing Industries and Construction (1.A.2)

3.2.7.1 Source category description

This section describes GHG emissions resulting from fuel combustion activities in manufacturing industries and construction.

This GHG emission inventory includes emissions from categories *1A2a – Iron and Steel*, *1A2b – Non-Ferrous Metals*, *1A2c – Chemicals*, *1A2d – Pulp, Paper and Print, 1A2e – Food Processing, Beverages and Tobacco*, *1A2f – Non-metallic minerals* and *1A2g – Other.*

In 2015, category *1A2 - Manufacturing Industries and Construction* was responsible for 12.64% of GHG emissions from fuel combustion activities (61.16% in 1990) and represented 10.38% of the total GHG emissions of Luxembourg, excluding LULUCF (49.22% in 1990). Compared to 2014, emissions of 1A2 decreased by 2.94%.

Table 3-27 summarizes GHG emissions for *1A2 – Manufacturing Industries and Construction* and the relevant sub-categories.

Regarding CO_2 emissions, *1A2 – Manufacturing Industries and Construction* is a key category, in 2015 for gaseous, liquid and solid fuels. It has been a key category for all these fuels from 1990 onwards: see Table 3-6 in Section 3.2.

Table 3-27 – GHG emission trends in CO_2e for IPCC sub-category 1A2 – Fuel Combustion Activities – Manufacturing Industries and Construction: 1990-2015

1A2 - Manufacturing Industries & Construction
GHG emissions by source & sink category (Gg)

Year	1A2a - Iron & Steel				1A2b - Non-Ferrous Metals				1A2c - Chemicals				1A2d - Pulp, Paper & Print			
	Total $CO_{2\,eq}$	CO_2	CH_4	N_2O	Total $CO_{2\,eq}$	CO_2	CH_4	N_2O	Total $CO_{2\,eq}$	CO_2	CH_4	N_2O	Total $CO_{2\,eq}$	CO_2	CH_4	N_2O
1990	5 411.38	*5 404.09*	*0.109*	*0.015*	28.39	*28.37*	*0.0005*	*0.0000*	170.19	*169.77*	*0.005*	*0.001*	NO	*IE*	*IE*	*IE*
1991	5 152.47	*5 145.46*	*0.104*	*0.015*	29.45	*29.42*	*0.0005*	*0.0000*	186.63	*186.09*	*0.007*	*0.001*	NO	*IE*	*IE*	*IE*
1992	4 754.78	*4 748.24*	*0.097*	*0.014*	29.70	*29.67*	*0.0005*	*0.0000*	173.89	*173.46*	*0.005*	*0.001*	NO	*IE*	*IE*	*IE*
1993	4 920.80	*4 913.79*	*0.104*	*0.015*	29.14	*29.12*	*0.0005*	*0.0000*	181.27	*180.81*	*0.006*	*0.001*	NO	*IE*	*IE*	*IE*
1994	4 067.15	*4 061.31*	*0.087*	*0.012*	35.44	*35.41*	*0.0006*	*0.0001*	200.52	*200.06*	*0.006*	*0.001*	NO	*IE*	*IE*	*IE*
1995	2 316.54	*2 313.30*	*0.049*	*0.007*	36.63	*36.60*	*0.0006*	*0.0001*	196.33	*195.98*	*0.005*	*0.001*	NO	*IE*	*IE*	*IE*
1996	2 101.65	*2 098.66*	*0.045*	*0.006*	58.99	*58.93*	*0.0010*	*0.0001*	199.63	*199.28*	*0.005*	*0.001*	NO	*IE*	*IE*	*IE*
1997	1 335.02	*1 333.16*	*0.028*	*0.004*	41.93	*41.89*	*0.0007*	*0.0001*	188.14	*187.86*	*0.004*	*0.001*	NO	*IE*	*IE*	*IE*
1998	310.75	*310.36*	*0.006*	*0.001*	43.80	*43.76*	*0.0008*	*0.0001*	189.48	*189.27*	*0.004*	*0.000*	NO	*IE*	*IE*	*IE*
1999	345.47	*345.02*	*0.007*	*0.001*	42.66	*42.62*	*0.0007*	*0.0001*	186.22	*186.00*	*0.004*	*0.000*	NO	*IE*	*IE*	*IE*
2000	332.65	*332.26*	*0.007*	*0.001*	41.45	*41.41*	*0.0007*	*0.0001*	207.55	*207.30*	*0.004*	*0.000*	12.90	*12.89*	*0.0003*	*0.0000*
2001	393.67	*393.22*	*0.008*	*0.001*	42.04	*42.00*	*0.0007*	*0.0001*	217.52	*217.27*	*0.004*	*0.001*	15.54	*15.52*	*0.0003*	*0.0000*
2002	375.25	*374.83*	*0.007*	*0.001*	40.36	*40.32*	*0.0007*	*0.0001*	215.28	*215.03*	*0.004*	*0.000*	19.25	*19.23*	*0.0004*	*0.0000*
2003	353.70	*353.34*	*0.006*	*0.001*	46.20	*46.16*	*0.0008*	*0.0001*	224.72	*224.47*	*0.004*	*0.000*	21.73	*21.71*	*0.0004*	*0.0000*
2004	385.95	*385.55*	*0.007*	*0.001*	52.65	*52.60*	*0.0009*	*0.0001*	231.70	*231.44*	*0.004*	*0.001*	19.06	*19.04*	*0.0004*	*0.0000*
2005	381.32	*380.94*	*0.007*	*0.001*	51.32	*51.28*	*0.0009*	*0.0001*	229.67	*229.42*	*0.004*	*0.000*	18.66	*18.63*	*0.0004*	*0.0000*
2006	447.26	*446.81*	*0.008*	*0.001*	56.45	*56.39*	*0.0010*	*0.0001*	217.79	*217.57*	*0.004*	*0.000*	11.51	*11.50*	*0.0002*	*0.0000*
2007	427.06	*426.64*	*0.008*	*0.001*	52.85	*52.80*	*0.0009*	*0.0001*	192.91	*192.71*	*0.004*	*0.000*	7.40	*7.39*	*0.0001*	*0.0000*
2008	407.18	*406.78*	*0.007*	*0.001*	51.37	*51.32*	*0.0009*	*0.0001*	191.11	*190.91*	*0.003*	*0.000*	10.08	*10.07*	*0.0002*	*0.0000*
2009	333.32	*333.00*	*0.006*	*0.001*	45.00	*44.95*	*0.0008*	*0.0001*	144.37	*144.22*	*0.003*	*0.000*	7.96	*7.95*	*0.0001*	*0.0000*
2010	382.09	*381.71*	*0.007*	*0.001*	52.95	*52.90*	*0.0009*	*0.0001*	171.03	*170.85*	*0.003*	*0.000*	5.28	*5.27*	*0.0001*	*0.0000*
2011	337.24	*336.91*	*0.006*	*0.001*	50.91	*50.86*	*0.0009*	*0.0001*	185.21	*185.02*	*0.003*	*0.000*	8.84	*8.83*	*0.0002*	*0.0000*
2012	302.20	*301.91*	*0.005*	*0.001*	51.42	*51.37*	*0.0009*	*0.0001*	180.66	*180.46*	*0.003*	*0.000*	10.77	*10.76*	*0.0002*	*0.0000*
2013	279.04	*278.77*	*0.005*	*0.001*	50.53	*50.49*	*0.0009*	*0.0001*	198.03	*197.80*	*0.004*	*0.000*	13.45	*13.44*	*0.0002*	*0.0000*
2014	275.32	*275.05*	*0.005*	*0.000*	49.36	*49.31*	*0.0009*	*0.0001*	160.18	*160.00*	*0.003*	*0.000*	6.90	*6.90*	*0.0001*	*0.0000*
2015	278.49	*278.22*	*0.005*	*0.000*	47.42	*47.37*	*0.0008*	*0.0001*	160.58	*160.37*	*0.003*	*0.000*	6.85	*6.84*	*0.0001*	*0.0000*
Trend 1990-2015	*-94.85%*	*-94.85%*	*-95.48%*	*-96.74%*	*67.03%*	*67.01%*	*80.65%*	*80.65%*	*-5.65%*	*-5.53%*	*-38.77%*	*-57.81%*	*NA*	*NA*	*NA*	*NA*
Trend 2014-2015	*1.15%*	*1.15%*	*1.38%*	*1.79%*	*-3.93%*	*-3.93%*	*-3.93%*	*-3.93%*	*0.25%*	*0.24%*	*5.53%*	*12.76%*	*-0.78%*	*-0.78%*	*-0.28%*	*0.60%*

Table continued on next page.

1A2 - Manufacturing Industries & Construction

GHG emissions by source & sink category (Gg)

Year	1A2e - Food Processing, Beverages & Tobacco				1A2f - Non-Metallic Minerals				1A2g - Other				1A2 - Manufacturing Industries & Construction			
	Total $CO_{2\,eq}$	CO_2	CH_4	N_2O	Total $CO_{2\,eq}$	CO_2 (excl. biomass)	CH_4 (incl. biomass)	N_2O (incl. biomass)	Total $CO_{2\,eq}$	CO_2 (excl. biomass)	CH_4 (incl. biomass)	N_2O (incl. biomass)	Total $CO_{2\,eq}$	CO_2 (excl. biomass)	CH_4 (incl. biomass)	N_2O (incl. biomass)
1990	8.18	*8.16*	*0.000*	*0.000*	539.07	*536.52*	*0.037*	*0.005*	108.17	*103.05*	*0.005*	*0.017*	6 265.38	*6 249.95*	*0.158*	*0.039*
1991	12.83	*12.80*	*0.000*	*0.000*	493.84	*491.49*	*0.034*	*0.005*	237.01	*231.10*	*0.008*	*0.019*	6 112.22	*6 096.36*	*0.154*	*0.040*
1992	12.50	*12.48*	*0.000*	*0.000*	538.08	*535.45*	*0.038*	*0.006*	264.62	*258.20*	*0.009*	*0.021*	5 773.57	*5 757.50*	*0.150*	*0.041*
1993	9.16	*9.14*	*0.000*	*0.000*	487.50	*485.25*	*0.033*	*0.005*	280.93	*274.02*	*0.008*	*0.022*	5 908.81	*5 892.13*	*0.152*	*0.043*
1994	12.12	*12.09*	*0.000*	*0.000*	591.20	*588.24*	*0.043*	*0.006*	289.69	*282.27*	*0.010*	*0.024*	5 196.12	*5 179.38*	*0.146*	*0.044*
1995	12.33	*12.30*	*0.000*	*0.000*	516.17	*513.79*	*0.035*	*0.005*	260.73	*252.83*	*0.008*	*0.026*	3 338.73	*3 324.81*	*0.097*	*0.039*
1996	10.88	*10.86*	*0.000*	*0.000*	544.28	*541.70*	*0.038*	*0.006*	269.48	*261.67*	*0.009*	*0.025*	3 184.91	*3 171.10*	*0.098*	*0.038*
1997	13.76	*13.73*	*0.000*	*0.000*	504.33	*502.03*	*0.034*	*0.005*	336.23	*327.77*	*0.010*	*0.028*	2 419.41	*2 406.43*	*0.077*	*0.037*
1998	12.88	*12.85*	*0.000*	*0.000*	467.18	*464.71*	*0.036*	*0.005*	349.59	*340.79*	*0.010*	*0.029*	1 373.69	*1 361.75*	*0.057*	*0.035*
1999	18.10	*18.05*	*0.001*	*0.000*	514.21	*511.59*	*0.038*	*0.006*	457.43	*447.44*	*0.014*	*0.032*	1 564.08	*1 550.71*	*0.064*	*0.039*
2000	25.07	*25.03*	*0.001*	*0.000*	532.12	*529.19*	*0.043*	*0.006*	245.17	*234.91*	*0.009*	*0.034*	1 396.92	*1 382.99*	*0.064*	*0.041*
2001	29.05	*28.99*	*0.001*	*0.000*	548.87	*545.34*	*0.053*	*0.007*	242.53	*231.95*	*0.008*	*0.035*	1 489.23	*1 474.29*	*0.075*	*0.044*
2002	31.40	*31.34*	*0.001*	*0.000*	453.22	*450.18*	*0.046*	*0.006*	240.02	*228.77*	*0.008*	*0.037*	1 374.78	*1 359.69*	*0.067*	*0.045*
2003	17.10	*17.07*	*0.000*	*0.000*	391.97	*389.23*	*0.041*	*0.006*	256.75	*245.63*	*0.008*	*0.037*	1 312.17	*1 297.60*	*0.062*	*0.044*
2004	17.07	*17.04*	*0.000*	*0.000*	445.17	*442.03*	*0.047*	*0.007*	256.82	*245.91*	*0.008*	*0.036*	1 408.41	*1 393.61*	*0.068*	*0.044*
2005	17.13	*17.10*	*0.000*	*0.000*	457.83	*454.59*	*0.049*	*0.007*	244.04	*232.26*	*0.034*	*0.037*	1 399.97	*1 384.22*	*0.095*	*0.045*
2006	12.62	*12.60*	*0.000*	*0.000*	494.78	*491.15*	*0.055*	*0.008*	237.09	*225.68*	*0.032*	*0.036*	1 477.50	*1 461.69*	*0.100*	*0.045*
2007	11.75	*11.74*	*0.000*	*0.000*	442.24	*438.92*	*0.050*	*0.007*	250.04	*238.58*	*0.034*	*0.036*	1 384.25	*1 368.79*	*0.097*	*0.044*
2008	11.61	*11.59*	*0.000*	*0.000*	426.22	*422.98*	*0.049*	*0.007*	226.80	*217.05*	*0.035*	*0.030*	1 324.36	*1 310.70*	*0.096*	*0.038*
2009	12.42	*12.40*	*0.000*	*0.000*	423.91	*421.03*	*0.043*	*0.006*	225.28	*216.47*	*0.029*	*0.027*	1 192.26	*1 180.01*	*0.082*	*0.034*
2010	11.35	*11.33*	*0.000*	*0.000*	415.06	*411.83*	*0.049*	*0.007*	234.23	*225.49*	*0.033*	*0.027*	1 271.99	*1 259.38*	*0.093*	*0.035*
2011	17.10	*17.08*	*0.000*	*0.000*	412.93	*409.82*	*0.047*	*0.006*	230.63	*222.33*	*0.030*	*0.025*	1 242.86	*1 230.86*	*0.087*	*0.033*
2012	13.65	*13.63*	*0.000*	*0.000*	402.16	*399.06*	*0.047*	*0.006*	225.27	*217.78*	*0.027*	*0.023*	1 186.12	*1 174.96*	*0.084*	*0.030*
2013	14.86	*14.84*	*0.000*	*0.000*	347.51	*344.46*	*0.046*	*0.006*	234.16	*226.53*	*0.027*	*0.023*	1 137.59	*1 126.32*	*0.084*	*0.031*
2014	20.53	*20.51*	*0.000*	*0.000*	392.90	*389.76*	*0.047*	*0.007*	245.02	*236.80*	*0.032*	*0.025*	1 150.22	*1 138.33*	*0.089*	*0.032*
2015	21.45	*21.43*	*0.000*	*0.000*	364.23	*361.46*	*0.042*	*0.006*	237.33	*229.68*	*0.030*	*0.023*	1 116.35	*1 105.38*	*0.082*	*0.030*
Trend 1990-2015	*162.18%*	*162.45%*	*78.01%*	*24.45%*	*-32.43%*	*-32.63%*	*12.74%*	*6.08%*	*119.41%*	*122.89%*	*471.60%*	*38.15%*	*-82.18%*	*-82.31%*	*-48.09%*	*-22.32%*
Trend 2014-2015	*4.48%*	*4.48%*	*8.62%*	*14.51%*	*-7.30%*	*-7.26%*	*-11.66%*	*-12.02%*	*-3.14%*	*-3.01%*	*-5.29%*	*-7.15%*	*-2.94%*	*-2.89%*	*-7.87%*	*-7.73%*

Source: Environment Agency.

Notes: CH_4 emissions are converted in CO_2e by multiplying the emissions by 25, *i.e.* the global warming potential (*GWP*) value for methane based on the effects of GHG over a 100-year time horizon.
N_2O emissions are converted in CO_2e by multiplying the emissions by 298, *i.e.* the global warming potential (*GWP*) value for nitrous oxide based on the effects of GHG over a 100-year time horizon.

3.2.7.2 Iron and Steel (1A2a)

3.2.7.2.1 Source category description

In 2015, fuel combustion in iron and steel was responsible for 3.15% of GHG emissions from fuel combustion activities (this share was 52.82% in 1990) and represented 2.59% of the total GHG emissions in CO_2eq, excluding LULUCF (42.51% in 1990). Compared to 2014, emissions have decreased by 1.15% and compared to 1990, by 94.85%.

3.2.7.2.2 Methodological issues

3.2.7.2.2.1 Activity Data

The iron and steel industry has been among the most important industrial activities in Luxembourg, both in terms of energy consumption and in terms of added value. As already stressed earlier in this report, important technological changes took place between 1993 and 1997 with the move from blast furnaces to electric arc furnaces. This led to large changes in air emissions. Today, the iron and steel industry has a specific energy consumption which is much lower than it was in 1990 but which is still relatively high at Luxembourg's scale.

Emissions from fuel combustion activities in the iron and steel industry are accounted for under category *1A2a – Iron &Steel*. CO_2 process related emissions are included under category *2C1 - Iron & Steel Production* (see Section **4.4.1** in Chapter 4).

Blast furnace gas is a side product of the iron produced in blast furnaces and can be used as fuel for combustion purposes. This was the case in Luxembourg until 1997, when the last blast furnace was blown out. Blast furnace gas was used by the iron and steel industry for heating purposes and for electricity production. Thus, blast furnace gas is to be considered as a secondary fuel. This has to be taken into account when comparing official energy balances (as published by the national statistics institute) with the energy balance used to prepare the emission inventories. Indeed, solid fuels, coke in particular, do not appear as fuel for combustion activities in blast furnaces in emission inventories, as these are mainly used for reduction purposes, and as such are considered in category *2C1 - Iron & Steel Production*. Instead of solid fuels, blast furnace gas (although considered as a solid fuel by the IPCC) is considered in category *1A2a* (see also Section 4.4.1.3 in the next chapter).

Table 3-28 gives a summary of which combustion activities are included for estimating GHG emissions pertaining to category *1A2a – Iron &Steel*.

Table 3-28 – Iron and steel combustion activities included in the GHG inventory

Combustion activity	SNAP[88] code
Combustion plants 50-300 MW	030102
Combustion plants <50 MW	030103
Blast Furnace Cowper's	030203
Sinter and pelletizing plants	030301
Reheating furnaces steel and iron	030302
Grey iron foundries	030303
Electric furnace steel plants	040207
Mobile Sources and Machinery in Industry	080800
Blast furnace gas distribution losses and flaring	NA

Combustion plants 50-300 MW

One power plant, operated until 1997 by the iron and steel industry, located on a site called *Terres Rouges,* and fed with blast furnace gas, residual fuel oil and/or natural gas. The activity rates are based on information received from the plant operator[89] and from a study (TÜV 1990). The electricity produced was used in the installations of the iron and steel industry (autoproducer). Overproduction was fed into the public electricity network.

Combustion plants <50 MW

Various combustion plants were operated mainly for heating purposes until 1997, when the last blast furnace was shut down. They were fed with blast furnace gas, residual fuel oil and/or natural gas. After 1997, these combustion plants were replaced by installations running on natural gas or gasoil. The related fuel consumption data were and still are received directly from the operator.

Blast furnace cowpers

Blast furnace cowpers have been used until 1997. They were fed with blast furnace gas and with natural gas. The related fuel consumption data were received directly from the operator.

Sinter and pelletizing plants

The sole sinter plant has been used until 1997. Its activity data, *i.e.* fuel consumption (coke oven coke, coal, blast furnace gas and natural gas) and production have been established in detail for the year 1990 based on information received from the operator. The fuel consumptions of the following years have been extrapolated based on the consumption data of 1990 and on the sintered ore production from 1990 - 1997.

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88 Technology oriented Standardized Nomenclature for Air Pollutants (SNAP)

89 Later Arcelor-Arbed, and now Arcelor-Mittal.

Reheating furnaces steel and iron

The reheating furnaces have been used during the whole period 1990 - 2014. Their operation is directly related to steel rolling. Their activity data (natural gas consumption) were received from the operator. In 2012, as a consequence of the economic crisis, the steel rolling facilities as well as the electric arc furnace on the site in Schifflange were temporarely switched off. In 2015, it was decided to finally close these facilities.

Grey iron foundries

The activity data (coking coke consumption) of those foundries have been estimated in the early 1990s (TÜV 1990), and no new data has been received since. Therefore, the values in the inventories have been kept rather constant. In 1997, grey iron production was stopped simultaneously with the last blast furnace.

Electric furnace steel plants

The first electric furnace steel plant appeared in 1994. Beside electric energy, natural gas is used for the fusion of scrap. The related fuel consumption data were received directly from the operator.

Blast Furnace Gas Distribution Losses and Flaring

A certain amount of blast furnace gas (BFG) is either lost during distribution or vented to avoid over-pressurization of the pipes or flared. The amount of BFG lost, vented or flared was obtained from the national statistics institute (STATEC).

Mobile Sources and Machinery in Industry

Activity data on the consumption of diesel oil, used in mobile sources and machinery was derived from energy balance as produced by the national statistics institute (STATEC). Since submission 2015, emissions of mobile machinery are reported under category *1.A.2.g.vii – Off-road vehicles and other machinery* (see section 3.2.7.8).

The fuel consumption data obtained by the operators (bottom-up) was then matched with the top-down data obtained from the national statistics institute (STATEC), in order to avoid double counting or underestimation.

Table 3-29 gives a summary of the amount of energy used in category *1A2a – Iron and Steel*.

Table 3-29 – Activity data for category *1A2a – Iron and Steel*: 1990-2015

1A2a - Iron & Steel *Activity Data by fuel type (GJ)*						
Year	Activity Total	Solid *Blast Furnace Gas, Coke Oven Coke, Coking Coke, Other Bituminous Coal*	Liquid *Residual Fuel Oil, Gas Oil*	Gaseous *Natural Gas*	Biomass	Other
1990	31 802 459	*24 297 184*	*632 309*	*6 872 966*	*NO*	*NO*
1991	29 861 529	*23 212 906*	*1 082 023*	*5 566 600*	*NO*	*NO*
1992	28 074 836	*21 153 539*	*1 543 162*	*5 378 135*	*NO*	*NO*
1993	28 969 294	*22 278 448*	*1 368 941*	*5 321 905*	*NO*	*NO*
1994	24 669 273	*18 169 300*	*1 249 467*	*5 250 506*	*NO*	*NO*
1995	16 128 469	*9 509 657*	*650 277*	*5 968 535*	*NO*	*NO*
1996	15 348 354	*8 471 037*	*559 065*	*6 318 252*	*NO*	*NO*
1997	11 405 449	*4 700 381*	*505 079*	*6 199 990*	*NO*	*NO*
1998	5 294 529	*NO*	*498 093*	*4 796 436*	*NO*	*NO*
1999	5 898 926	*NO*	*634 967*	*5 263 959*	*NO*	*NO*
2000	5 797 134	*NO*	*360 167*	*5 436 967*	*NO*	*NO*
2001	6 869 204	*NO*	*385 452*	*6 483 752*	*NO*	*NO*
2002	6 541 567	*NO*	*339 077*	*6 202 490*	*NO*	*NO*
2003	6 222 254	*NO*	*91 251*	*6 131 003*	*NO*	*NO*
2004	6 756 649	*NO*	*153 569*	*6 603 080*	*NO*	*NO*
2005	6 662 816	*NO*	*103 627*	*6 559 189*	*NO*	*NO*
2006	7 814 064	*NO*	*79 708*	*7 734 356*	*NO*	*NO*
2007	7 492 698	*NO*	*64 889*	*7 427 809*	*NO*	*NO*
2008	7 165 454	*NO*	*43 438*	*7 122 017*	*NO*	*NO*
2009	5 827 171	*NO*	*30 926*	*5 796 245*	*NO*	*NO*
2010	6 707 857	*NO*	*75 512*	*6 632 346*	*NO*	*NO*
2011	5 899 917	*NO*	*40 643*	*5 859 274*	*NO*	*NO*
2012	5 312 148	*NO*	*12 569*	*5 299 579*	*NO*	*NO*
2013	4 912 710	*NO*	*18 295*	*4 894 415*	*NO*	*NO*
2014	4 842 432	*NO*	*12 497*	*4 829 935*	*NO*	*NO*
2015	4 895 754	*NO*	*19 391*	*4 876 363*	*NO*	*NO*
Trend 1990-2015	*-84.61%*	*NA*	*-96.93%*	*-29.05%*	*NA*	*NA*
Trend 2014-2015	*1.10%*	*NA*	*55.16%*	*0.96%*	*NA*	*NA*

Source: Environment Agency.

3.2.7.2.2.2 Methodological choices

The 2006 IPCC Guidelines Tier 1 approach has been applied for residual fuel oil and solid fuels except for blast furnace gas (recorded under solid fuels according to the 2006 IPCC Guidelines). For natural gas, gas oil, diesel oil and blast furnace gas, the methodological approach is classified as a Tier 2 methodology as country-specific emissions factor were used.

Special care was taken with solid fuels to avoid double counting with IPCC sub-category *2C1 - Iron and Steel Production*. As already stated (§ 3.2.7.2.2.1), the use of natural gas and BFG is considered as a combustion activity under 1A2a, whereas the use of coal (other bituminous coal), coke oven coke and some residual fuel oil was used in the blast furnaces to produce BFG and for reduction purposes. These emissions are accounted for in category 2C1.

3.2.7.2.2.3 Emission factors

Default emission factors are derived from 2006 IPCC Guidelines. Country-specific or plant specific emission factors were determined by the Environment Agency and are either derived from a study (TÜV 1990) or were calculated from specific data accessible to the Environment Agency from the operator (Table 3-30).

For blast furnace gas combusted in blast furnaces or combustion plants, a plant specific CO_2 emission factor, which is at the same time country-specific as there was only one plant in Luxembourg, was applied. This EF was derived from a study in the year 1990 and is based on measurements of BFG composition (see also section 3.2.5.3). The CH_4 and N_2O emission factors are default values from the 2006 IPCC Guidelines. The CO_2 EF for BFG lost in distribution and flaring is also plant specific and was based on measurements and BFG composition.[80] Generally, BFG consists of about 60 percent nitrogen, 18-20% carbon dioxide and some oxygen. The rest is mostly carbon monoxide, which has a fairly low heating value. When calculating the emissions from distribution losses, it is assumed that BFG is completely oxidised to CO_2 in the atmosphere. Therefore, the same emission factor as for flaring was used. No default values for CH_4 and N_2O from BFG lost in distribution and flaring are given neither in the 1996 Revised IPCC Guidelines nor in the 2006 IPCC Guidelines, therefore the default values for coal were applied.

Table 3-30 gives an overview of the different emission factors used in this submission.

Table 3-30 – Emission factors for category *1A2a – Iron and Steel*

1A2a Iron & Steel *Emission Factors for 2015 (kg/TJ)*								
Fuel	**Fuel Type**	**CO_2**		**CH_4**		**N_2O**		**Source**
		EF	***type***	***EF***	***type***	***EF***	***type***	
Blast furnace gas	solid	*257 181*	*PS, CS*	*1.00*	*D*	*0.10*	*D*	*TüV 1990* *2006 IPCC GL*
BFG (DistLoss&Flar)	solid	*245 323*	*PS, CS*	*1.00*	*D*	*0.10*	*D*	*TüV 1990* *2006 IPCC GL*
Coke Oven Coke	solid	*107 000*	*D*	*10.00*	*D*	*1.50*	*D*	*2006 IPCC GL*
Other Bituminous Coal	solid	*94 600*	*D*	*10.00*	*D*	*1.50*	*D*	*2006 IPCC GL*
Coking Coke	solid	*94 600*	*D*	*10.00*	*D*	*1.50*	*D*	*2006 IPCC GL*
Residual Fuel Oil	liquid	*77 400*	*D*	*3.00*	*D*	*0.60*	*D*	*2006 IPCC GL*
Gas Oil	liquid	*73 858*	*CS*	*3.00*	*D*	*0.60*	*D*	*AEV* *2006 IPCC GL*
Natural Gas	gaseous	*56 760*	*CS*	*1.00*	*D*	*0.10*	*D*	*AEV* *2006 IPCC GL*

Source: Environment Agency.

Table 3-31 gives an overview of the evolution of the implied emission factors per fuel type.

Time-series are considered to be consistent, also in comparison with energy data as reported by the national statistics institute. For solid fuels, the relatively high CO_2 IEF, compared to usual solid fuels, stems from the fact that blast furnace gas is the predominant fuel in this category. Other solid fuels, such as coke oven coke, other bituminous coal or coking coal only played a minor role, and were mainly used in the sole sinter and pelletizing plant and in grey iron foundries. For liquid fuels, the CO_2 IEF was higher in the early 1990s due to the increased use of residual fuel oil, which was replaced by gas/diesel oil with the switch to electric arc steel production.

Table 3-31 – Implied emission factors for IPCC sub-category 1A2a – Iron and Steel

1A2a Iron & Steel – *Implied Emission Factors (kg/TJ)*									
Year	Solid			Liquid			Gaseous		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
1990	204 087	4.13	0.59	76 542	3.00	0.60	57 755	1.00	0.10
1991	204 235	4.11	0.58	76 830	3.00	0.60	57 743	1.00	0.10
1992	204 137	4.11	0.58	77 053	3.00	0.60	57 848	1.00	0.10
1993	202 008	4.24	0.60	76 891	3.00	0.60	57 894	1.00	0.10
1994	201 498	4.27	0.61	76 839	3.00	0.60	57 940	1.00	0.10
1995	201 690	4.27	0.61	76 201	3.00	0.60	57 929	1.00	0.10
1996	199 816	4.37	0.62	75 874	3.00	0.60	57 546	1.00	0.10
1997	200 038	4.37	0.62	75 706	3.00	0.60	57 205	1.00	0.10
1998	NO	NO	NO	75 530	3.00	0.60	56 863	1.00	0.10
1999	NO	NO	NO	74 789	3.00	0.60	56 522	1.00	0.10
2000	NO	NO	NO	73 827	3.00	0.60	56 221	1.00	0.10
2001	NO	NO	NO	73 825	3.00	0.60	56 258	1.00	0.10
2002	NO	NO	NO	73 825	3.00	0.60	56 396	1.00	0.10
2003	NO	NO	NO	73 844	3.00	0.60	56 533	1.00	0.10
2004	NO	NO	NO	73 870	3.00	0.60	56 671	1.00	0.10
2005	NO	NO	NO	73 882	3.00	0.60	56 910	1.00	0.10
2006	NO	NO	NO	73 876	3.00	0.60	57 008	1.00	0.10
2007	NO	NO	NO	73 862	3.00	0.60	56 793	1.00	0.10
2008	NO	NO	NO	73 874	3.00	0.60	56 665	1.00	0.10
2009	NO	NO	NO	73 867	3.00	0.60	57 056	1.00	0.10
2010	NO	NO	NO	73 867	3.00	0.60	56 712	1.00	0.10
2011	NO	NO	NO	73 859	3.00	0.60	56 988	1.00	0.10
2012	NO	NO	NO	73 852	3.00	0.60	56 793	1.00	0.10
2013	NO	NO	NO	73 862	3.00	0.60	56 680	1.00	0.10
2014	NO	NO	NO	73 874	3.00	0.60	56 756	1.00	0.10
2015	NO	NO	NO	73 858	3.00	0.60	56 760	1.00	0.10

Source: Environment Agency.

3.2.7.3 Non-Ferrous Metals (1A2b)

3.2.7.3.1 Source category description

In Luxembourg, non-ferrous metals activities cover mainly secondary aluminium production from aluminium scrap.

In 2015, fuel combustion due to non-ferrous metal production was responsible for 0.54% of GHG emissions from fuel combustion activities (0.28% in 1990) and represented 0.44% of the national total GHG emissions in CO_2e, excluding LULUCF (0.22% in 1990). Compared to 2013, emissions decreased by 3.93% and compared to 1990, they increased by 67.03%.

3.2.7.3.2 Methodological issues & time series consistency

3.2.7.3.2.1 Activity data

Liquefied petroleum gas (*LPG*) was an important fuel used in the secondary aluminium production. It was slowly substituted by natural gas. Generally, the fuel consumption data were obtained from the operators. The activity data for secondary aluminium production are listed in Table 3-32.

The activity data reported here is the data reported by the operators to the Environment Agency through their annual reporting obligations. This bottom-up data could not be matched with top-down data from the national statistics institute as no such data is reported for this category. Due to confidentiality reasons, this data is reported under the iron & steel industry by national statistics. However, to avoid double counting, the bottom-up data was subtracted from the top-down data from official statistics reported for category *1A2a - Iron and Steel*.

Table 3-32 - Activity data for category *1A2b - Non-Ferrous Metals*: 1990-2015

1A2b - Non-Ferrous Metals *Activity Data by fuel type (GJ)*						
Year	Activity Total	Solid	Liquid *LPG*	Gaseous *Natural Gas*	Biomass	Other
1990	462 005	NO	230 000	232 005	NO	NO
1991	480 174	NO	230 000	250 174	NO	NO
1992	484 471	NO	230 000	254 471	NO	NO
1993	474 992	NO	230 000	244 992	NO	NO
1994	574 091	NO	307 372	266 719	NO	NO
1995	593 787	NO	314 594	279 193	NO	NO
1996	983 700	NO	314 594	669 106	NO	NO
1997	724 596	NO	56 951	667 645	NO	NO
1998	757 076	NO	87 447	669 629	NO	NO
1999	740 541	NO	86 796	653 745	NO	NO
2000	722 935	NO	88 251	634 683	NO	NO
2001	733 199	NO	86 796	646 403	NO	NO
2002	715 027	NO	NO	715 027	NO	NO
2003	816 432	NO	NO	816 432	NO	NO
2004	928 110	NO	NO	928 110	NO	NO
2005	900 989	NO	NO	900 989	NO	NO
2006	989 225	NO	NO	989 225	NO	NO
2007	929 759	NO	NO	929 759	NO	NO
2008	905 641	NO	NO	905 641	NO	NO
2009	787 899	NO	NO	787 899	NO	NO
2010	932 798	NO	NO	932 798	NO	NO
2011	892 430	NO	NO	892 430	NO	NO
2012	904 473	NO	NO	904 473	NO	NO
2013	890 705	NO	NO	890 705	NO	NO
2014	868 802	NO	NO	868 802	NO	NO
2015	834 626	NO	NO	834 626	NO	NO
Trend 1990-2015	80.65%	NA	NA	259.74%	NA	NA
Trend 2014-2015	-3.93%	NA	NA	-3.93%	NA	NA

Source: Environment Agency.

3.2.7.3.2.2 Methodological choices

The 2006 IPCC Guidelines Tier 2 approach has been applied for liquid (LPG) and gaseous fuels (natural gas).

3.2.7.3.2.3 Emission factors

Country-specific EFs for CO_2 from LPG and natural gas were used. Default EFs from the 2006 IPCC Guidelines have been applied for CH_4 and N_2O (Table 3-33).

Table 3-33 – Emission factors for category 1A2b – Non-Ferrous Metals

1A2b - Non-Ferrous Metals *Emission Factors for 2015 (kg/TJ)*								
Fuel	Fuel Type	CO_2 EF	CO_2 type	CH_4 EF	CH_4 type	N_2O EF	N_2O type	Source
LPG	liquid	*64 933*	*CS*	*1.00*	*D*	*0.10*	*D*	*AEV 2006 IPCC GL*
Natural Gas	gaseous	*56 760*	*CS*	*1.00*	*D*	*0.10*	*D*	*AEV 2006 IPCC GL*

Source: Environment Agency.

3.2.7.4 Chemicals (1A2c)

3.2.7.4.1 Source category description

In Luxembourg, chemical activities cover mainly the production of tyres, various plastic films and synthetic non-woven textiles. Also included in this category are the emissions of two gas turbines operated by the chemical industry for heat and electricity production (autoproducers).

In 2015, fuel combustion from the chemical industry was responsible for 1.82% of GHG emissions from fuel combustion activities (1.66% in 1990) and represented 1.49% of the national total GHG emissions, excluding LULUCF (1.34% in 1990). Compared to 2014, emissions increased by 0.25% and compared to 1990, decreased by 5.65%.

3.2.7.4.2 Methodological issues & time-series consistency

3.2.7.4.2.1 Activity data

Annual fuel consumption data of residual fuel oil, gas oil, diesel oil and natural gas were obtained from the operators. Diesel oil is mainly used by mobile sources and machinery, whereas the remaining fuels are mainly combusted in stationary units for heating purposes.

The activity data reported here is the data reported by the operators to the Environment Agency through their annual reporting obligations. The bottom-up data on natural gas, between 1990 and 1999, could not be matched to the top-down data from the national statistics institute as no such data is reported for this category. To avoid double counting, the bottom-up data for this period was subtracted from the top-down data from official statistics reported for category *1A2g - Other*. For natural gas (2000-2015) and liquid fuels (residual fuel oil, gas oil, diesel oil) the matching exercise was done within the category 1A2c as top-down data is reported for this category by the national statistics institute. Activity data for the chemical industry are listed in Table 3-34.

Fluctuations in activity data may occur, due to temporal shut-down of installations (*e.g.* for maintenance). This may then be reflected in the activity data by a sharp decrease as happened in 2007 in comparison to the year 2006: a decrease of about 9% occurred due to maintenance on one of the gas turbines operated by the chemical industry.[90] The dip in 2009 is explained by the global economic downturn due to the financial and economic crisis. 2010 showed a slight recovery, with a stabilisation until 2013. The decrease observed in 2014 is mainly due to the phase out of one of the gas turbines, being replaced by energy efficient boilers.

Table 3-34- Activity data for category *1A2c - Chemicals*: 1990-2015

1A2c - Chemicals *Activity Data by fuel type (GJ)*						
Year	**Activity Total**	**Solid**	**Liquid** *Residual Fuel Oil, Gas Oil*	**Gaseous** *Natural Gas*	**Biomass**	**Other**
1990	2 455 706	*NO*	*1 460 983*	*994 723*	*NO*	*NO*
1991	2 563 192	*NO*	*1 975 924*	*587 269*	*NO*	*NO*
1992	2 520 181	*NO*	*1 453 902*	*1 066 279*	*NO*	*NO*
1993	2 597 533	*NO*	*1 595 269*	*1 002 264*	*NO*	*NO*
1994	2 964 983	*NO*	*1 490 527*	*1 474 456*	*NO*	*NO*
1995	3 096 655	*NO*	*895 987*	*2 200 668*	*NO*	*NO*
1996	3 166 826	*NO*	*905 480*	*2 261 347*	*NO*	*NO*
1997	3 105 924	*NO*	*541 574*	*2 564 350*	*NO*	*NO*
1998	3 282 717	*NO*	*145 022*	*3 137 695*	*NO*	*NO*
1999	3 223 167	*NO*	*211 883*	*3 011 284*	*NO*	*NO*
2000	3 618 830	*NO*	*218 707*	*3 400 122*	*NO*	*NO*
2001	3 782 763	*NO*	*253 681*	*3 529 081*	*NO*	*NO*
2002	3 744 542	*NO*	*220 952*	*3 523 590*	*NO*	*NO*
2003	3 918 509	*NO*	*170 242*	*3 748 267*	*NO*	*NO*
2004	4 023 985	*NO*	*197 211*	*3 826 775*	*NO*	*NO*
2005	3 979 273	*NO*	*174 153*	*3 805 119*	*NO*	*NO*
2006	3 791 898	*NO*	*82 726*	*3 709 171*	*NO*	*NO*
2007	3 373 071	*NO*	*66 911*	*3 306 160*	*NO*	*NO*
2008	3 356 005	*NO*	*43 290*	*3 312 715*	*NO*	*NO*
2009	2 516 649	*NO*	*37 602*	*2 479 048*	*NO*	*NO*
2010	2 989 910	*NO*	*74 942*	*2 914 968*	*NO*	*NO*
2011	3 226 530	*NO*	*68 167*	*3 158 363*	*NO*	*NO*
2012	3 127 706	*NO*	*165 874*	*2 961 833*	*NO*	*NO*
2013	3 419 020	*NO*	*233 257*	*3 185 763*	*NO*	*NO*
2014	2 765 555	*NO*	*177 315*	*2 588 240*	*NO*	*NO*
2015	2 742 591	*NO*	*275 120*	*2 467 472*	*NO*	*NO*
Trend 1990-2015	*11.68%*	*NA*	*-81.17%*	*148.06%*	*NA*	*NA*
Trend 2014-2015	*-0.83%*	*NA*	*55.16%*	*-4.67%*	*NA*	*NA*

Source: Environment Agency.

3.2.7.4.2.2 Methodological issues

The 2006 IPCC Guidelines Tier 1 approach has been applied for residual fuel oil, whereas the 2006 IPCC Guidelines Tier 2 approach was applied for, gas oil and natural gas.

90 ARR 2009, § 61.

3.2.7.4.2.3 Emission factors

The 2006 IPCC Guidelines default EFs have been applied for CO_2 for residual fuel oil, whereas for gas oil and natural gas country-specific EFs were used. Default EFs have been applied for CH_4 and N_2O (Table 3-35).

Table 3-35 – Emission factors for category *1A2c – Chemicals*

1A2c - Chemicals *Emission Factors for 2015 (kg/TJ)*								
Fuel	**Fuel Type**	***CO_2***		***CH_4***		***N_2O***		***Source***
		EF	***type***	***EF***	***type***	***EF***	***type***	
Residual Fuel Oil	liquid	*77 400*	*D*	*3.00*	*D*	*0.60*	*D*	*2006 IPCC GL*
Gas Oil	liquid	*73 858*	*CS*	*3.00*	*D*	*0.60*	*D*	*AEV 2006 IPCC GL*
Natural Gas	gaseous	*56 760*	*CS*	*1.00*	*D*	*0.10*	*D*	*AEV 2006 IPCC GL*

Source: Environment Agency.

Table 3-36 gives an overview of the evolution of the implied emission factors per fuel type.

For liquid fuels, the CO_2 IEF was higher in the early 1990s due to the increased use of residual fuel oil, which was gradually replaced by gas/diesel oil in the mid 1990s.

Table 3-36 – Implied emission factors for category *1A2c – Chemicals*

1A2c - Chemicals *Implied Emission Factors (kg/TJ)*						
Year	**Liquid**			**Gaseous**		
	CO_2	***CH_4***	***N_2O***	***CO_2***	***CH_4***	***N_2O***
1990	*76 879*	*3.00*	*0.60*	*57 755*	*1.00*	*0.10*
1991	*77 019*	*3.00*	*0.60*	*57 743*	*1.00*	*0.10*
1992	*76 882*	*3.00*	*0.60*	*57 848*	*1.00*	*0.10*
1993	*76 968*	*3.00*	*0.60*	*57 894*	*1.00*	*0.10*
1994	*76 907*	*3.00*	*0.60*	*57 940*	*1.00*	*0.10*
1995	*76 454*	*3.00*	*0.60*	*57 929*	*1.00*	*0.10*
1996	*76 366*	*3.00*	*0.60*	*57 546*	*1.00*	*0.10*
1997	*76 013*	*3.00*	*0.60*	*57 205*	*1.00*	*0.10*
1998	*74 815*	*3.00*	*0.60*	*56 863*	*1.00*	*0.10*
1999	*74 555*	*3.00*	*0.60*	*56 522*	*1.00*	*0.10*
2000	*73 827*	*3.00*	*0.60*	*56 221*	*1.00*	*0.10*
2001	*73 825*	*3.00*	*0.60*	*56 258*	*1.00*	*0.10*
2002	*73 825*	*3.00*	*0.60*	*56 396*	*1.00*	*0.10*
2003	*73 844*	*3.00*	*0.60*	*56 533*	*1.00*	*0.10*
2004	*73 870*	*3.00*	*0.60*	*56 671*	*1.00*	*0.10*
2005	*73 882*	*3.00*	*0.60*	*56 910*	*1.00*	*0.10*
2006	*73 876*	*3.00*	*0.60*	*57 008*	*1.00*	*0.10*
2007	*73 862*	*3.00*	*0.60*	*56 793*	*1.00*	*0.10*
2008	*73 874*	*3.00*	*0.60*	*56 665*	*1.00*	*0.10*
2009	*73 867*	*3.00*	*0.60*	*57 056*	*1.00*	*0.10*
2010	*73 867*	*3.00*	*0.60*	*56 712*	*1.00*	*0.10*
2011	*73 859*	*3.00*	*0.60*	*56 988*	*1.00*	*0.10*
2012	*73 852*	*3.00*	*0.60*	*56 793*	*1.00*	*0.10*
2013	*73 862*	*3.00*	*0.60*	*56 680*	*1.00*	*0.10*
2014	*73 874*	*3.00*	*0.60*	*56 756*	*1.00*	*0.10*
2015	*73 858*	*3.00*	*0.60*	*56 760*	*1.00*	*0.10*

Source: Environment Agency.

3.2.7.5 Pulp, Paper and Print (1A2d)

3.2.7.5.1 Source category description

In Luxembourg, this source category only covers the printing industry. No pulp or paper production occurs in Luxembourg. Included in this sub-category are the emissions from combustion plants (<50 MW). Emissions from mobile sources and machinery used in this category are reported under category *1.A.2.g.vii – Off-road vehicles and other machinery*.

In 2015, fuel combustion from the paper and print industry was responsible for 0.08% of GHG emissions from fuel combustion activities and represented 0.06% of the national total GHG emissions in CO_2e, excluding LULUCF. Compared to 2014, emissions decreased by 0.78%.

3.2.7.5.2 Methodological issues

3.2.7.5.2.1 Activity data

Annual fuel consumption data for gas oil, diesel oil and natural gas were derived from national statistics for the period 2000-2015. Diesel oil is mainly used by mobile sources and machinery (reported under category *1.A.2.g.vii – Off-road vehicles and other machinery*), whereas the remaining fuels are mainly combusted in stationary units for heating purposes. For 1990-1999, no activity data is available from national statistics, hence the notation key IE was used in the CRF tables. For these years the data is included in *1A2g - Other*.

Activity data for the pulp, paper and print industry are listed in Table 3-37.

Table 3-37- Activity data for category *1A2d - Pulp, Paper and Print*: 1990-2015

Year	Activity Total	Solid	Liquid *Gas Oil, Diesel Oil*	Gaseous *Natural Gas*	Biomass	Other
		1A2d - Pulp, Paper & Print *Activity Data by fuel type (GJ)*				
1990	IE	*NO*	*IE*	*IE*	*NO*	*NO*
1991	IE	*NO*	*IE*	*IE*	*NO*	*NO*
1992	IE	*NO*	*IE*	*IE*	*NO*	*NO*
1993	IE	*NO*	*IE*	*IE*	*NO*	*NO*
1994	IE	*NO*	*IE*	*IE*	*NO*	*NO*
1995	IE	*NO*	*IE*	*IE*	*NO*	*NO*
1996	IE	*NO*	*IE*	*IE*	*NO*	*NO*
1997	IE	*NO*	*IE*	*IE*	*NO*	*NO*
1998	IE	*NO*	*IE*	*IE*	*NO*	*NO*
1999	IE	*NO*	*IE*	*IE*	*NO*	*NO*
2000	222 948	*NO*	*19 980*	*202 968*	*NO*	*NO*
2001	266 625	*NO*	*29 781*	*236 843*	*NO*	*NO*
2002	331 511	*NO*	*30 456*	*301 055*	*NO*	*NO*
2003	378 444	*NO*	*17 956*	*360 488*	*NO*	*NO*
2004	329 795	*NO*	*20 482*	*309 314*	*NO*	*NO*
2005	323 026	*NO*	*14 804*	*308 222*	*NO*	*NO*
2006	199 751	*NO*	*6 580*	*193 171*	*NO*	*NO*
2007	128 782	*NO*	*4 379*	*124 403*	*NO*	*NO*
2008	176 705	*NO*	*3 210*	*173 495*	*NO*	*NO*
2009	138 612	*NO*	*2 327*	*136 285*	*NO*	*NO*
2010	91 744	*NO*	*3 932*	*87 812*	*NO*	*NO*
2011	154 293	*NO*	*2 195*	*152 098*	*NO*	*NO*
2012	189 025	*NO*	*1 217*	*187 807*	*NO*	*NO*
2013	236 545	*NO*	*1 631*	*234 914*	*NO*	*NO*
2014	121 336	*NO*	*658*	*120 677*	*NO*	*NO*
2015	120 264	*NO*	*1 021*	*119 243*	*NO*	*NO*
Trend 1990-2015	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Trend 2014-2015	*-0.88%*	*NA*	*55.16%*	*-1.19%*	*NA*	*NA*

Source: Environment Agency.

3.2.7.5.2.2 Methodological choices

The 2006 IPCC Guidelines Tier 2 approach was applied for gas oil and natural gas.

3.2.7.5.2.3 Emission factors

Country-specific CO_2 EFs were used for gasoil and natural gas, whereas 2006 IPCC default EFs have been applied for CH_4 and N_2O (Table 3-38).

Table 3-38 – Emission factors for category *1A2d - Pulp, Paper and Print*

Fuel	Fuel Type	CO_2 EF	CO_2 type	CH_4 EF	CH_4 type	N_2O EF	N_2O type	Source
				1A2d - Pulp, Paper & Print *Emission Factors for 2015 (kg/TJ)*				
Gas Oil	liquid	*73 858*	*CS*	*3.00*	*D*	*0.60*	*D*	*AEV* *2006 IPCC GL*
Natural Gas	gaseous	*56 760*	*CS*	*1.00*	*D*	*0.10*	*D*	*AEV* *2006 IPCC GL*

Source: Environment Agency

Table 3-39 gives an overview of the evolution of the implied emission factors per fuel type.

Table 3-39 – Implied emission factors for category *1A2d - Pulp, Paper and Print*

Year	1A2d - Pulp, Paper & Print Implied Emission Factors (kg/TJ) Liquid			Gaseous		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
1990	NO	NO	NO	NO	NO	NO
1991	NO	NO	NO	NO	NO	NO
1992	NO	NO	NO	NO	NO	NO
1993	NO	NO	NO	NO	NO	NO
1994	NO	NO	NO	NO	NO	NO
1995	NO	NO	NO	NO	NO	NO
1996	NO	NO	NO	NO	NO	NO
1997	NO	NO	NO	NO	NO	NO
1998	NO	NO	NO	NO	NO	NO
1999	NO	NO	NO	NO	NO	NO
2000	73 827	3.00	0.60	56 221	1.00	0.10
2001	73 825	3.00	0.60	56 258	1.00	0.10
2002	73 825	3.00	0.60	56 396	1.00	0.10
2003	73 844	3.00	0.60	56 533	1.00	0.10
2004	73 870	3.00	0.60	56 671	1.00	0.10
2005	73 882	3.00	0.60	56 910	1.00	0.10
2006	73 876	3.00	0.60	57 008	1.00	0.10
2007	73 862	3.00	0.60	56 793	1.00	0.10
2008	73 874	3.00	0.60	56 665	1.00	0.10
2009	73 867	3.00	0.60	57 056	1.00	0.10
2010	73 867	3.00	0.60	56 712	1.00	0.10
2011	73 859	3.00	0.60	56 988	1.00	0.10
2012	73 852	3.00	0.60	56 793	1.00	0.10
2013	73 862	3.00	0.60	56 680	1.00	0.10
2014	73 874	3.00	0.60	56 756	1.00	0.10
2015	73 858	3.00	0.60	56 760	1.00	0.10

Source: Environment Agency

3.2.7.6 Food Processing, Beverages and Tobacco (1A2e)

3.2.7.6.1 Source category description

In Luxembourg, this category covers mainly the production of beer, milk, milk products, and tobacco products. Included in this category are the emissions from combustion plants (<50 MW) operated by the food processing, beverages and tobacco industry. Emissions from mobile sources and machinery used in this category are reported under category *1.A.2.g.vii – Off-road vehicles and other machinery*.

In 2015, fuel combustion from the food processing, beverages and tobacco industry was responsible for 0.24% of GHG emissions from fuel combustion activities (0.08% in 1990) and represented 0.20% of the national total GHG emissions excluding LULUCF (0.06% in 1990). Compared to 2014, emissions increased by 4.48% and compared to 1990, increased by 162.18%.

3.2.7.6.2 Methodological issues & time-series consistency

3.2.7.6.2.1 Activity data

Annual fuel consumption data of residual fuel oil, gas oil, diesel oil and natural gas were obtained from the operators. Diesel oil is mainly used by mobile sources and machinery (reported under category *1.A.2.g.vii – Off-road vehicles and other machinery*), whereas the remaining fuels are mainly combusted in stationary units for heating purposes. The use of residual fuel oil stopped in 2002.

The activity data reported here is the data reported by the operators to the Environment Agency through their annual reporting obligations. The bottom-up data on natural gas, for 1990-1999, could not be matched to the top-down data from national statistics as no such data is reported for this category. To avoid double counting, the bottom-up data on natural gas was subtracted from the top-down data from national statistics reported for category *1A2g - Other*. For natural gas (2000-2015) and liquid fuels (residual fuel oil, gas oil, diesel oil), the matching exercise was done within the category 1A2e as top-down data is available for this sub-category from national statistics. Activity data for the food processing, beverages and tobacco industry are listed in Table 3-40.

Table 3-40- Activity data for category *1A2e - Food Processing, Beverages and Tobacco*: 1990-2015

1A2e - Food Processing, Beverages & Tobacco *Activity Data by fuel type (GJ)*						
Year	Activity Total	Solid	Liquid *Residual fuel oil, Gas Oil, Diesel Oil*	Gaseous *Natural Gas*	Biomass	Other
1990	123 939	NO	58 127	65 812	NO	NO
1991	193 080	NO	97 625	95 455	NO	NO
1992	190 024	NO	89 556	100 468	NO	NO
1993	144 772	NO	46 041	98 731	NO	NO
1994	185 088	NO	84 354	100 734	NO	NO
1995	188 732	NO	84 363	104 369	NO	NO
1996	169 396	NO	66 232	103 164	NO	NO
1997	209 521	NO	103 053	106 468	NO	NO
1998	199 012	NO	88 135	110 877	NO	NO
1999	266 940	NO	170 840	96 100	NO	NO
2000	414 541	NO	97 766	316 776	NO	NO
2001	476 809	NO	123 547	353 262	NO	NO
2002	518 726	NO	119 963	398 763	NO	NO
2003	282 284	NO	64 125	218 159	NO	NO
2004	279 706	NO	69 246	210 460	NO	NO
2005	282 624	NO	59 979	222 646	NO	NO
2006	212 414	NO	29 092	183 321	NO	NO
2007	199 630	NO	23 453	176 177	NO	NO
2008	198 292	NO	20 580	177 712	NO	NO
2009	201 656	NO	53 165	148 492	NO	NO
2010	190 480	NO	30 903	159 577	NO	NO
2011	294 158	NO	18 719	275 438	NO	NO
2012	233 514	NO	21 476	212 037	NO	NO
2013	252 551	NO	30 563	221 988	NO	NO
2014	355 645	NO	18 985	336 660	NO	NO
2015	368 642	NO	29 457	339 185	NO	NO
Trend 1990-2015	197.44%	NA	-49.32%	415.38%	NA	NA
Trend 2014-2015	3.65%	NA	55.16%	0.75%	NA	NA

Source: Environment Agency.

3.2.7.6.2.2 Methodological choices

The 2006 IPCC Guidelines Tier 1 approach has been applied for residual fuel oil whereas the 2006 IPCC Guidelines Tier 2 approach was applied for gas oil, diesel oil and natural gas.

3.2.7.6.2.3 Emission factors

The 2006 IPCC Guidelines default EFs have been applied for CO_2 from residual fuel oil, whereas for gasoil and natural gas country specific EFs were used. Default EFs have been applied for CH_4 and N_2O (Table 3-41).

Table 3-41 – Emission factors for category *1A2e – Food Processing, Beverages and Tobacco*

1A2e - Food Processing, Beverages & Tobacco *Emission Factors for 2015 (kg/TJ)*								
Fuel	**Fuel Type**	***CO_2***		***CH_4***		***N_2O***		***Source***
		EF	***type***	***EF***	***type***	***EF***	***type***	
Residual Fuel Oil	liquid	*77 400*	*D*	*3.00*	*D*	*0.60*	*D*	*2006 IPCC GL*
Gas Oil	liquid	*73 858*	*CS*	*3.00*	*D*	*0.60*	*D*	*AEV* *2006 IPCC GL*
Natural Gas	gaseous	*56 760*	*CS*	*1.00*	*D*	*0.10*	*D*	*AEV* *2006 IPCC GL*

Source: Environment Agency

Table 3-42 gives an overview of the evolution of the implied emission factors per fuel type.

Table 3-42 – Implied emission factors for category *1A2e – Food Processing, Beverages and Tobacco*

1A2e - Food Processing, Beverages & Tobacco *Implied Emission Factors (kg/TJ)*						
Year	Liquid			Gaseous		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
1990	75 067	3.00	0.60	57 755	1.00	0.10
1991	74 636	3.00	0.60	57 743	1.00	0.10
1992	74 415	3.00	0.60	57 848	1.00	0.10
1993	74 462	3.00	0.60	57 894	1.00	0.10
1994	74 172	3.00	0.60	57 940	1.00	0.10
1995	74 167	3.00	0.60	57 929	1.00	0.10
1996	74 328	3.00	0.60	57 546	1.00	0.10
1997	74 100	3.00	0.60	57 205	1.00	0.10
1998	74 319	3.00	0.60	56 863	1.00	0.10
1999	73 871	3.00	0.60	56 522	1.00	0.10
2000	73 856	3.00	0.60	56 221	1.00	0.10
2001	73 828	3.00	0.60	56 258	1.00	0.10
2002	73 825	3.00	0.60	56 396	1.00	0.10
2003	73 844	3.00	0.60	56 533	1.00	0.10
2004	73 870	3.00	0.60	56 671	1.00	0.10
2005	73 882	3.00	0.60	56 910	1.00	0.10
2006	73 876	3.00	0.60	57 008	1.00	0.10
2007	73 862	3.00	0.60	56 793	1.00	0.10
2008	73 874	3.00	0.60	56 665	1.00	0.10
2009	73 867	3.00	0.60	57 056	1.00	0.10
2010	73 867	3.00	0.60	56 712	1.00	0.10
2011	73 859	3.00	0.60	56 988	1.00	0.10
2012	73 852	3.00	0.60	56 793	1.00	0.10
2013	73 862	3.00	0.60	56 680	1.00	0.10
2014	73 874	3.00	0.60	56 756	1.00	0.10
2015	73 858	3.00	0.60	56 760	1.00	0.10

Source: Environment Agency

The higher CO_2 IEF for liquid fuels in the early 1990s is due to the partial use of residual fuel oil in combustion plants. Residual fuel oil was then mainly phased out, which is reflected in a decreasing IEF.

3.2.7.7 Non-Metallic Minerals (1A2f)

3.2.7.7.1 Source category description

Source category *1A2f – Non-metallic minerals* covers industrial activities such as glass, clinker / cement and ceramics production.

In 2015, fuel combustion emissions reported under *1A2f – Non-metallic minerals* were responsible for 4.12% of GHG emissions from fuel combustion activities (this share was 5.26% in 1990) and represented 3.39% of the national total GHG emissions excluding LULUCF (4.23% in 1990). Compared to 2014, emissions decreased by 7.30% and compared to 1990, decreased by 28.67%.

3.2.7.7.2 Methodological issues

3.2.7.7.2.1 Activity data

Under *1A2f – Non-metallic minerals*, the following activities have been considered (Table 3-47):

Table 3-43 – Combustion activities included in *1A2f – Non-metallic minerals*

Description	SNAP code
Cement (Clinker)	030311
Flat glass	030314
Fine ceramic materials	030320

Cement (Clinker)

One industrial site produces clinker in Luxembourg. Its major fuel is other bituminous coal, but use is also made of residual oil, natural gas and special types of waste: shredded tyres, fluff and sewage sludge. These waste types contain a certain biogenic fraction, which is annually reported by the operator. This is taken into consideration when estimating the emissions. The consumption data of these fuels are transmitted annually to the Environment Agency by the operator.

Flat glass

There are two flat glass plants in Luxembourg. Their main fuel is natural gas. LPG was used in the past, but only on a minor scale.

Fine ceramic materials

One major production site of ceramic materials existed in Luxembourg (Villeroy & Boch) using natural gas as fuel. However, the production site was closed down in 2010.

Activity data for the non-metallic minerals industry are listed in Table 3-48.

Table 3-44 – Activity data by fuel type of category *1A2f – Non-metallic minerals*: 1990-2015

1A2f - Non-Metallic Minerals *Activity Data by fuel type (GJ)*						
Year	Activity Total	Solid	Liquid *Residual fuel oil, Gas Oil, LPG*	Gaseous *Natural Gas*	Biomass *sewage sludge, tyres, fluff*	Other *tyres, fluff*
1990	7 102 444	*3 302 589*	*317 025*	*3 482 830*	*NO*	*NO*
1991	6 490 994	*3 028 845*	*343 117*	*3 119 032*	*NO*	*NO*
1992	6 977 309	*3 404 630*	*464 838*	*3 107 842*	*NO*	*NO*
1993	6 460 877	*2 850 457*	*452 944*	*3 157 476*	*NO*	*NO*
1994	7 600 107	*3 840 609*	*483 627*	*3 275 872*	*NO*	*NO*
1995	6 849 114	*3 000 573*	*475 977*	*3 372 564*	*NO*	*NO*
1996	7 166 300	*3 303 931*	*453 964*	*3 408 405*	*NO*	*NO*
1997	6 742 841	*2 886 032*	*550 191*	*3 306 618*	*NO*	*NO*
1998	6 070 347	*2 674 118*	*446 318*	*2 949 911*	*48 484*	*131 088*
1999	6 797 343	*2 819 127*	*529 094*	*3 449 122*	*47 267*	*127 797*
2000	6 910 110	*3 127 895*	*221 546*	*3 560 670*	*72 479*	*195 963*
2001	6 849 270	*3 119 891*	*186 247*	*3 543 132*	*157 603*	*426 112*
2002	5 736 177	*2 093 325*	*159 806*	*3 483 046*	*199 718*	*502 711*
2003	4 920 038	*1 793 790*	*170 106*	*2 956 142*	*210 845*	*457 295*
2004	5 594 036	*2 070 876*	*210 865*	*3 312 295*	*268 490*	*492 303*
2005	5 681 249	*2 190 698*	*157 346*	*3 333 205*	*246 562*	*527 312*
2006	6 008 418	*2 577 804*	*144 293*	*3 286 321*	*276 011*	*565 623*
2007	5 495 109	*1 989 234*	*133 697*	*3 372 178*	*313 212*	*572 010*
2008	5 246 572	*1 805 356*	*100 434*	*3 340 782*	*270 238*	*649 169*
2009	5 395 370	*2 043 207*	*37 557*	*3 314 606*	*218 574*	*433 991*
2010	5 101 937	*1 855 755*	*23 877*	*3 222 306*	*301 932*	*601 195*
2011	5 104 308	*1 819 386*	*29 527*	*3 255 395*	*274 250*	*576 457*
2012	4 956 495	*1 742 721*	*32 119*	*3 181 655*	*282 003*	*591 243*
2013	4 029 126	*1 657 980*	*27 785*	*2 343 360*	*292 689*	*613 050*
2014	4 742 368	*1 792 071*	*57 737*	*2 892 559*	*277 558*	*605 407*
2015	4 517 383	*1 527 342*	*46 425*	*2 943 615*	*255 302*	*530 784*
Trend 1990-2015	*-36.40%*	*-53.75%*	*-85.36%*	*-15.48%*	*NA*	*NA*
Trend 2014-2015	*-4.74%*	*-14.77%*	*-19.59%*	*1.77%*	*-8.02%*	*-12.33%*

Source: Environment Agency

3.2.7.7.2.2 Methodological choices

The 2006 IPCC Guidelines Tier 1 approach has been applied for solid fuels and residual fuel oil, whereas the 2006 IPCC Guidelines Tier 2 approach was applied for natural gas, gas oil and LPG. CO_2 emissions from the biogenic fractions of tires, fluff and sewage sludge are reported under memory items. The biogenic fraction of tires, which are used since 1998 in the clinker production, was set to 27% for the entire time-series, in accordance with the EU-ETS declarations from the plant operator. This value is validated by two independent reports from "Verein Deutscher Zementwerke e. V."[91] and "Aliapur"[92] on the use of tires as secondary fuels.

91 http://www.vdz-online.de/fileadmin/gruppen/vdz/3LiteraturRecherche/Taetigkeitsbericht07/VDZ_Kap_II.pdf

92 http://www.aliapur.fr/media/files/RetD_new/Conferences_Publications/Pneus_usages_comme_combustible_alternatif_extrait.pdf

The biogenic fraction of fluff, which is used since 2006 as secondary fuel in the clinker production, is determined annually by the plant operator, in accordance with the EU Emissions Trading System Monitoring and Reporting Guidelines[93].

3.2.7.7.2.3 Emission factors

The 2006 IPCC Guidelines default CO_2 EFs have been applied for residual fuel oil and for solid fuels except for tires and fluff, where plant-specific emission factors were used. For natural gas, gas oil and LPG country-specific EFs were used. IPCC default EFs have been applied for CH_4 and N_2O (Table 3-49).

Table 3-45 – Emission factors for category *1A2f – Non-metallic minerals*

1A2f - Non-Metallic Minerals *Emission Factors for 2015 (kg/TJ)*								
Fuel	**Fuel Type**	***CO_2***		***CH_4***		***N_2O***		***Source***
		EF	***type***	***EF***	***type***	***EF***	***type***	
Other Bituminous Coal	solid	*94 600*	*D*	*10.00*	*D*	*1.50*	*D*	*2006 IPCC GL*
Residual Fuel Oil	liquid	*77 400*	*D*	*3.00*	*D*	*0.60*	*D*	*2006 IPCC GL*
Gas Oil	liquid	*73 858*	*CS*	*3.00*	*D*	*0.60*	*D*	*AEV 2006 IPCC GL*
LPG	liquid	*64 933*	*CS*	*1.00*	*D*	*0.10*	*D*	*AEV 2006 IPCC GL*
Natural Gas	gaseous	*56 760*	*CS*	*1.00*	*D*	*0.10*	*D*	*AEV 2006 IPCC GL*
Sewage Sludge	biomass	*100 000*	*D*	*30.00*	*D*	*4.00*	*D*	*2006 IPCC GL*
Tires	other/biomass	*88 000*	*PS*	*30.00*	*D*	*4.00*	*D*	*ETS 2006 IPCC GL*
Fluff	other/biomass	*87 090*	*PS*	*30.00*	*D*	*4.00*	*D*	*ETS 2006 IPCC GL*

Source: Environment Agency

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Table 3-50 gives an overview of the evolution of the implied emission factors per fuel type.

The increase of the CO_2 IEF of biomass from 2002 onwards is due to the use of different types of biomass over time. Indeed, tires (CO_2 EF: 88.00 t CO_2/TJ) are used since 1998 as secondary fuel in the clinker production. Since 2002, sewage sludge (CO_2 EF: 100.00 t CO_2/TJ) and since 2006, fluff, (CO_2 EF: 87.09 t CO_2/TJ) are co-incinerated in the clinker production.

93 http://ec.europa.eu/clima/policies/ets/monitoring/index_en.htm

Table 3-46 – Implied emission factors for category *1A2f – Non-metallic minerals*

Year	Solid			Liquid			Gaseous			Biomass			Other		
	1A2f - Non-Metallic Minerals – Implied Emission Factors (kg/TJ)														
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
1990	94 600	10.00	1.50	72 369	2.18	0.40	57 755	1.00	0.10	NO	NO	NO	NO	NO	NO
1991	94 600	10.00	1.50	72 451	2.46	0.46	57 743	1.00	0.10	NO	NO	NO	NO	NO	NO
1992	94 600	10.00	1.50	72 263	2.39	0.45	57 848	1.00	0.10	NO	NO	NO	NO	NO	NO
1993	94 600	10.00	1.50	72 410	2.46	0.46	57 894	1.00	0.10	NO	NO	NO	NO	NO	NO
1994	94 600	10.00	1.50	72 609	2.54	0.48	57 940	1.00	0.10	NO	NO	NO	NO	NO	NO
1995	94 600	10.00	1.50	72 630	2.55	0.49	57 929	1.00	0.10	NO	NO	NO	NO	NO	NO
1996	94 600	10.00	1.50	72 702	2.57	0.49	57 546	1.00	0.10	NO	NO	NO	NO	NO	NO
1997	94 600	10.00	1.50	72 437	2.47	0.47	57 205	1.00	0.10	NO	NO	NO	NO	NO	NO
1998	94 600	10.00	1.50	72 741	2.58	0.50	56 863	1.00	0.10	88 000	30.00	4.00	88 000	30.00	4.00
1999	94 600	10.00	1.50	73 156	2.72	0.53	56 522	1.00	0.10	88 000	30.00	4.00	88 000	30.00	4.00
2000	94 600	10.00	1.50	71 600	2.16	0.39	56 221	1.00	0.10	88 000	30.00	4.00	88 000	30.00	4.00
2001	94 600	10.00	1.50	71 784	2.23	0.41	56 258	1.00	0.10	88 000	30.00	4.00	88 000	30.00	4.00
2002	94 600	10.00	1.50	71 839	2.25	0.41	56 396	1.00	0.10	88 828	30.00	4.00	88 000	30.00	4.00
2003	94 600	10.00	1.50	71 567	2.14	0.39	56 533	1.00	0.10	90 374	30.00	4.00	88 000	30.00	4.00
2004	94 600	10.00	1.50	71 578	2.15	0.39	56 671	1.00	0.10	91 862	30.00	4.00	88 000	30.00	4.00
2005	94 600	10.00	1.50	71 546	2.14	0.38	56 910	1.00	0.10	90 508	30.00	4.00	88 000	30.00	4.00
2006	94 600	10.00	1.50	71 363	2.07	0.37	57 008	1.00	0.10	90 549	30.00	4.00	87 761	30.00	4.00
2007	94 600	10.00	1.50	71 325	2.06	0.36	56 793	1.00	0.10	90 128	30.00	4.00	86 870	30.00	4.00
2008	94 600	10.00	1.50	71 588	2.16	0.39	56 665	1.00	0.10	89 254	30.00	4.00	85 796	30.00	4.00
2009	94 600	10.00	1.50	73 867	3.00	0.60	57 056	1.00	0.10	93 035	30.00	4.00	82 596	30.00	4.00
2010	94 600	10.00	1.50	73 867	3.00	0.60	56 712	1.00	0.10	91 543	30.00	4.00	86 112	30.00	4.00
2011	94 600	10.00	1.50	73 859	3.00	0.60	56 988	1.00	0.10	90 767	30.00	4.00	86 752	30.00	4.00
2012	94 600	10.00	1.50	73 852	3.00	0.60	56 793	1.00	0.10	89 911	30.00	4.00	86 489	30.00	4.00
2013	94 600	10.00	1.50	73 862	3.00	0.60	56 680	1.00	0.10	88 728	30.00	4.00	86 034	30.00	4.00
2014	94 600	10.00	1.50	73 874	3.00	0.60	56 756	1.00	0.10	87 636	30.00	4.00	85 559	30.00	4.00
2015	94 600	10.00	1.50	73 858	3.00	0.60	56 760	1.00	0.10	90 056	30.00	4.00	87 547	30.00	4.00

Source: Environment Agency

3.2.7.8 Other (1A2g)

3.2.7.8.1 Source category description

Source category *1A2g – Other* covers all the remaining industrial activities not previously mentioned and is divided into two sub-categories:

- *1.A.2.g.vii – Off-road vehicles and other machinery*, which includes all types of mobile machinery used in *1A2 - Manufacturing industry and Construction*, such as power generators, fork lifts, excavators, etc.
- *1.A.2.g.viii – Other Manufacturing Industries*, which includes stationary combustion in manufacturing of transport equipment, machinery, mining and quarrying, wood and wood products, construction, textile and leather and non-specified industry.

In 2015, fuel combustion emissions reported under *1A2g - Other* manufacturing industries and construction were responsible for 2.69% of GHG emissions from fuel combustion activities (this share was 1.06% in 1990) and represented 2.21% of the national total GHG emissions excluding LULUCF (0.85% in 1990). Compared to 2014, emissions decreased by 3.14% and compared to 1990, increased by 119.41%.

3.2.7.8.2 Methodological issues

3.2.7.8.2.1 Activity data

The following combustion activities have been considered in category *1A2g - Other* (Table 3-47):

Table 3-47 – Combustion activities included in 1A2g - Other

Description	SNAP code

Combustion plants < 50 MW	030103
Gas Turbines	030104
Asphalt concrete plants	030313
Other mobile sources and machinery in Industry	080800
Other mobile equipment	081000

Combustion plants <50 MW

This source includes all kind of smaller combustion installations for heat or steam production. As the number of this kind of boilers is quite important, they have not always been treated individually. Various types of fuel were and still are used: anthracite, residual fuel oil, gas oil, LPG, natural gas. Where information about the fuel combustion in these boilers was available, it was received directly from the operator.

Gas Turbines

This source includes one gas turbine used in the wood processing industry for heat and electricity production running on natural gas. The information about the fuel combustion is received directly from the operator.

Asphalt concrete plants

There are three asphalt concrete plants in Luxembourg. Their main fuel is lignite (brown coal briquettes) followed by natural gas and gas oil. Fuel consumption data was obtained by the operators.

Mobile Sources and Machinery in Industry and Other Mobile Equipment

Activity data is based on the stock data of mobile machinery used in industry and constructuion equipment, as well as on economic indicators such as the gross value added for the indusrial sector.

Activity data for *1A2g – Other* is listed in Table 3-48.

Table 3-48 – Activity data by fuel type of category *1A2g – Other*: 1990-2015

		1A2g - Other *Activity Data by fuel type (GJ)*					
Year	Activity Total (excl. biomass)	*1.A.2.g.vii - Off-road vehicles and other machinery*	*1.A.2.g.viii - Other Manufacturing Industries*				
		Liquid	Solid	Liquid	Gaseous	Biomass	Other
		Diesel Oil, Gasoline	*Other Bituminous Coal, Brown Coal Briquettes*	*Residual fuel oil, Gas Oil, LPG*	*Natural Gas*	*Wood and Wood Waste*	
1990	1 419 507	*618 365*	*206 140*	*182 270*	*412 732*	*NO*	*NO*
1991	3 579 480	*700 883*	*199 769*	*293 602*	*2 385 225*	*NO*	*NO*
1992	4 033 301	*760 284*	*217 880*	*251 723*	*2 803 414*	*NO*	*NO*
1993	4 331 590	*824 978*	*161 445*	*225 392*	*3 119 774*	*NO*	*NO*
1994	4 341 613	*866 765*	*320 437*	*251 136*	*2 903 275*	*NO*	*NO*
1995	3 922 129	*922 207*	*160 119*	*264 601*	*2 575 201*	*NO*	*NO*
1996	4 052 202	*892 581*	*254 976*	*219 399*	*2 685 246*	*NO*	*NO*
1997	5 230 936	*950 701*	*225 135*	*220 194*	*3 834 907*	*NO*	*NO*
1998	5 473 713	*971 738*	*183 946*	*409 668*	*3 908 361*	*NO*	*NO*
1999	7 008 697	*1 056 669*	*218 107*	*1 615 072*	*4 118 849*	*NO*	*NO*
2000	3 477 699	*1 111 339*	*232 377*	*761 453*	*1 372 530*	*NO*	*NO*
2001	3 438 918	*1 140 315*	*168 958*	*814 564*	*1 315 081*	*NO*	*NO*
2002	3 368 858	*1 268 813*	*138 204*	*798 707*	*1 163 134*	*NO*	*NO*
2003	3 592 172	*1 320 679*	*145 892*	*999 409*	*1 126 193*	*NO*	*NO*
2004	3 610 210	*1 393 702*	*147 911*	*813 874*	*1 254 724*	*NO*	*NO*
2005	3 408 202	*1 396 170*	*144 819*	*658 450*	*1 208 763*	*880 933*	*NO*
2006	3 329 157	*1 505 873*	*136 831*	*398 084*	*1 288 369*	*856 579*	*NO*
2007	3 459 157	*1 837 824*	*142 414*	*422 212*	*1 056 706*	*918 261*	*NO*
2008	3 137 870	*1 711 519*	*139 665*	*379 344*	*907 342*	*979 662*	*NO*
2009	3 095 614	*1 733 024*	*156 912*	*313 845*	*891 832*	*754 820*	*NO*
2010	3 154 305	*1 799 877*	*211 674*	*382 244*	*760 510*	*863 371*	*NO*
2011	3 146 903	*1 905 351*	*171 154*	*216 820*	*853 577*	*785 914*	*NO*
2012	3 083 416	*1 821 734*	*191 369*	*210 269*	*860 045*	*682 906*	*NO*
2013	3 250 406	*1 934 875*	*135 996*	*204 410*	*975 125*	*715 237*	*NO*
2014	3 368 210	*2 198 490*	*147 760*	*117 054*	*904 905*	*872 512*	*NO*
2015	3 213 764	*2 131 555*	*188 807*	*184 967*	*708 435*	*807 701*	*NO*
Trend 1990-2015	126.40%	*244.71%*	*-8.41%*	*1.48%*	*71.65%*	*NA*	*NA*
Trend 2014-2015	*-4.59%*	*-3.04%*	*27.78%*	*58.02%*	*-21.71%*	*-7.43%*	*NA*

Source: Environment Agency

3.2.7.8.2.2 Methodological choices

For CO_2, the 2006 IPCC Guidelines Tier 1 approach has been applied for solid fuels, residual fuel oil and biomass fuels (wood and wood waste), whereas the 2006 IPCC Guidelines Tier 2 approach was applied for natural gas, gas oil, diesel oil, gasoline and LPG. For CH_4 and N_2O from stationary combustion, the 2006 IPCC Guidelines Tier 1 approach has been applied for all fuels.

For CH_4 and N_2O from off-road vehicles and other machinery, the GEORG (Grazer Emissionsmodell für Off-Road Geräte) model developed by the TU Graz was used. This methodology conforms to the requirements of the IPCC 2006 GL Tier 3 methodology. Input data to the model are:

- Machinery stock data (obtained through inquiries and statistical extrapolation);
- Assumptions on drop-out rates of machinery (broken down machinery will be replaced);
- Operating time (obtained through inquiries), related to age of machinery.

From machinery stock data and drop-out rates an age structure of the off-road machinery was obtained by GEORG. Four categories of engine types were considered. Depending on the fuel consumption of the engine the ratio power of the engine was calculated. Emissions were calculated by multiplying an engine specific emission factor (expressed in g/kWh) by the average engine power, the operating time and the number of vehicles.

3.2.7.8.2.3 Emission factors

The 2006 IPCC Guidelines default CO_2 EFs have been applied for biomass fuels, residual fuel oil and for solid fuels. For natural gas, gas oil, diesel oil, gasoline and LPG country-specific EFs were used. For stationary combustion, IPCC default EFs have been applied for CH_4 and N_2O.

For mobile combustion (diesel oil and motor gasoline), country-specific values, derived from the GEORG model, have been applied for CH_4 and N_2O (Table 3-49).

Table 3-49 – Emission factors for category *1A2g – Other*

1A2g - Other *Emission Factors for 2015 (kg/TJ)*								
Fuel	**Fuel Type**	***CO_2***		***CH_4***		***N_2O***		***Source***
		EF	***type***	***EF***	***type***	***EF***	***type***	
Other Bituminous Coal	solid	*94 600*	*D*	*10.00*	*D*	*1.50*	*D*	*2006 IPCC GL*
Brown Coal Briquettes	solid	*97 500*	*D*	*10.00*	*D*	*1.50*	*D*	*2006 IPCC GL*
Residual Fuel Oil	liquid	*77 400*	*D*	*3.00*	*D*	*0.60*	*D*	*2006 IPCC GL*
Gas Oil	liquid	*73 858*	*CS*	*3.00*	*D*	*0.60*	*D*	*AEV 2006 IPCC GL*
Diesel Oil	liquid	*73 858*	*CS*	*1.21*	*CS*	*9.16*	*CS*	*AEV*
Gasoline	liquid	*71 551*	*CS*	*28.14*	*CS*	*1.62*	*CS*	*AEV*
LPG	liquid	*64 933*	*CS*	*1.00*	*D*	*0.10*	*D*	*AEV 2006 IPCC GL*
Natural Gas	gaseous	*56 760*	*CS*	*1.00*	*D*	*0.10*	*D*	*AEV 2006 IPCC GL*
Wood / wood wastes	biomass	*112 000*	*D*	*30.00*	*D*	*4.00*	*D*	*2006 IPCC GL*

Source: Environment Agency

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Table 3-50 gives an overview of the evolution of the implied emission factors for liquid fuels used by off-road vehicles and other machinery.

Table 3-50 – Implied emission factors for category *1.A.2.g.vii – Off-road vehicles and other machinery*

1.A.2.g.vii - Off-road vehicles and other machinery *Implied Emission Factors (kg/TJ)*			
Year	Liquid		
	CO_2	CH_4	N_2O
1990	73 852	3.68	26.34
1991	73 866	3.67	26.37
1992	73 893	3.66	26.39
1993	73 852	3.65	26.41
1994	73 829	3.60	26.71
1995	73 824	3.50	27.30
1996	73 833	3.44	27.65
1997	73 832	3.37	28.10
1998	73 839	3.27	28.68
1999	73 836	3.18	29.27
2000	73 809	3.11	29.69
2001	73 806	3.07	29.95
2002	73 806	2.81	28.77
2003	73 826	2.53	27.23
2004	73 852	2.32	25.30
2005	73 864	2.15	23.36
2006	73 859	1.97	21.06
2007	73 845	1.74	17.11
2008	73 858	1.65	14.87
2009	73 851	1.60	13.69
2010	73 850	1.56	12.51
2011	73 842	1.51	11.41
2012	73 835	1.48	10.80
2013	73 847	1.45	10.37
2014	73 860	1.40	9.57
2015	73 845	1.36	9.12

Source: Environment Agency

Table 3-51 gives an overview of the evolution of the implied emission factors for fuels used in stationary combustion by other manufacturing industries.

Table 3-51 – Implied emission factors for category 1.A.2.g.viii – Other manufacturing industries

1.A.2.g.viii - Other Manufacturing Industries

Implied Emission Factors (kg/TJ)

Year	Solid			Liquid			Gaseous			Biomass		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
1990	97 393	10.00	1.50	73 871	3.00	0.60	57 755	1.00	0.10	NO	NO	NO
1991	97 411	10.00	1.50	75 394	3.00	0.60	57 743	1.00	0.10	NO	NO	NO
1992	97 419	10.00	1.50	73 986	3.00	0.60	57 848	1.00	0.10	NO	NO	NO
1993	97 376	10.00	1.50	74 339	3.00	0.60	57 894	1.00	0.10	NO	NO	NO
1994	97 438	10.00	1.50	74 995	3.00	0.60	57 940	1.00	0.10	NO	NO	NO
1995	97 374	10.00	1.50	75 506	3.00	0.60	57 929	1.00	0.10	NO	NO	NO
1996	97 430	10.00	1.50	74 731	3.00	0.60	57 546	1.00	0.10	NO	NO	NO
1997	97 447	10.00	1.50	73 851	3.00	0.60	57 205	1.00	0.10	NO	NO	NO
1998	97 401	10.00	1.50	70 507	2.25	0.41	56 863	1.00	0.10	NO	NO	NO
1999	97 445	10.00	1.50	71 428	2.43	0.46	56 522	1.00	0.10	NO	NO	NO
2000	97 500	10.00	1.50	69 682	1.89	0.32	56 221	1.00	0.10	NO	NO	NO
2001	97 500	10.00	1.50	70 380	2.03	0.36	56 258	1.00	0.10	NO	NO	NO
2002	97 500	10.00	1.50	70 177	1.99	0.35	56 396	1.00	0.10	NO	NO	NO
2003	97 500	10.00	1.50	70 274	2.09	0.37	56 533	1.00	0.10	NO	NO	NO
2004	97 500	10.00	1.50	70 597	2.21	0.40	56 671	1.00	0.10	NO	NO	NO
2005	97 500	10.00	1.50	70 194	2.15	0.39	56 910	1.00	0.10	112 000	30.00	4.00
2006	97 500	10.00	1.50	69 497	2.02	0.35	57 008	1.00	0.10	112 000	30.00	4.00
2007	97 500	10.00	1.50	68 618	1.83	0.31	56 793	1.00	0.10	112 000	30.00	4.00
2008	97 500	10.00	1.50	67 516	1.58	0.24	56 665	1.00	0.10	112 000	30.00	4.00
2009	97 500	10.00	1.50	71 050	2.11	0.38	57 056	1.00	0.10	112 000	30.00	4.00
2010	97 500	10.00	1.50	75 337	2.99	0.60	56 712	1.00	0.10	112 000	30.00	4.00
2011	97 500	10.00	1.50	75 202	3.00	0.60	56 988	1.00	0.10	112 000	30.00	4.00
2012	97 500	10.00	1.50	75 004	3.00	0.60	56 793	1.00	0.10	112 000	30.00	4.00
2013	97 500	10.00	1.50	73 923	3.00	0.60	56 680	1.00	0.10	112 000	30.00	4.00
2014	97 500	10.00	1.50	73 893	2.98	0.60	56 756	1.00	0.10	112 000	30.00	4.00
2015	97 500	10.00	1.50	73 813	2.99	0.60	56 760	1.00	0.10	112 000	30.00	4.00

Source: Environment Agency

3.2.7.9 Uncertainties and time-series consistency

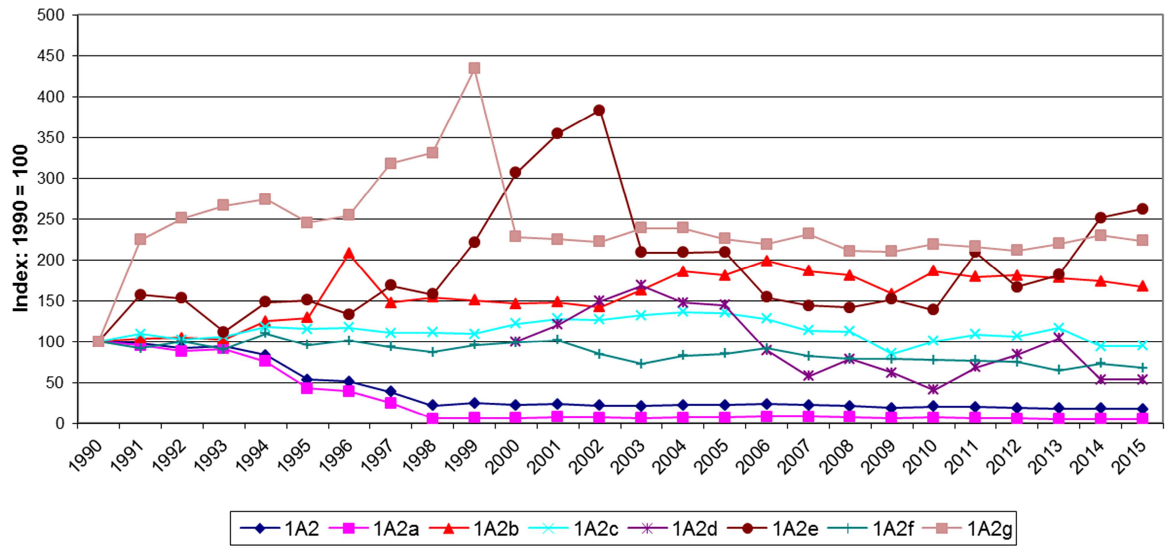
The uncertainties for activity data and emission factors used for IPCC category *1A2 – Manufacturing Industries and Construction* are presented in Table 3-52.

Table 3-52: uncertainties for activity data and emission factors used for IPCC category 1A2 – Manufacturing Industries and Construction.

IPCC category/Group	Gas	Activity data uncertainty (%)	Emission factor uncertainty (%)
1A2 - Gaseous Fuels	CO2	2%	1%
1A2 - Gaseous Fuels	CH4	2%	50%
1A2 - Gaseous Fuels	N2O	2%	50%
1A2 - Liquid Fuels	CO2	2%	1%
1A2 - Liquid Fuels	CH4	2%	50%
1A2 - Liquid Fuels	N2O	2%	50%
1A2 - Other Fuels	CO2	8%	20%
1A2 - Other Fuels	CH4	8%	50%
1A2 - Other Fuels	N2O	8%	50%
1A2 - Biomass	CH4	7%	50%
1A2 - Biomass	N2O	7%	60%
1A2 - Solid Fuels	CO2	1%	3%
1A2 - Solid Fuels	CH4	1%	50%
1A2 - Solid Fuels	N2O	1%	50%

Generally, the time-series, as reported in category *1A2 - Manufacturing Industries and Construction* are considered to be consistent (Figure 3-6).

Figure 3-6 – GHG emission trend indexes for category *1A2 – Manufacturing Industries and Construction*: 1990-2015



The general trend of GHG emissions in *1A2* is greatly influenced by sub-category *1A2a - Iron and Steel*. Fluctuations in emissions of the other sub-categories only influence the general trend on a minor scale.

However, at a deeper level, and especially for categories *1A2d*, *1A2e* and *1A2g*, time series seem to be less consistent. This is either due to the lack of specific activity data (for example for *1A2d*, no category-specific AD is available for the years 1990-1999, so that notation key *IE* is used, and the corresponding emissions are reported under *1A2g*), or due to short-term switches in the energy mix (rotation of gasoil stocks), maintenance stops, closure or start-up of new facilities, etc.

For more specific information on time-series consistency, please refer to the methodological issues as described in the respective categories above.

3.2.7.10 Source-specific QA/QC and verification

Activity data for large facilities that have reporting obligations under the European Union Emission Trading System (EU-ETS) is cross-checked between two sources: reports obtained directly from (1) the operator under its operational permit obligations and (2) the EU-ETS registry operator. Both are hosted at the Environment Agency. A list with the large energy consuming facilities along with their respective fuel consumption has been compiled and enables the Single National Entity to quickly cross-check this data with the EU-ETS data. Thus, completeness can be checked on a more systematic basis.

Additionally, cross checks with other relevant sectors, mainly sector *2 – Industrial Processes and Product Use*, are performed to avoid double counting.

Finally, consistency and completeness checks are performed using the tools embedded in CRF Reporter.

3.2.7.11 Category-specific recalculations including changes made in response to the review process

Table 3-53 presents the main revisions and recalculations done since the last submission to the UNFCCC and relevant to category *1A2 - Manufacturing Industries and Construction*. For the quantitative aspect of these recalculations, plese refer to Chapter 10.

Table 3-53 – Recalculations done since submission 2016v1

GHG source & sink category	Revisions 2016v1 ➔ 2017v1.2	Type of revision
1A2	Fuel consumption data for natural gas, gasoil and diesel oil was revised due to revised energy balance from the national statistics institute	updated AD
1A2	Major revisions in the energy balance have been done for natural gas allocated to the categories 1.A.2 – Manufacturing industries and construction and 1.A.4 – Other sectors for the years 2000-2014. See text below for details	Updated AD
1A2gvii	Activity data has been updated according to a recent study[94].	Updated AD
1A2gvii	The country-specific CO2 emission factor for motor gasoline was changed from a fixed value of 72'000 kg CO_2/TJ to a country-specific emission factor based on a weighted average of the EFs of the countries from where motor gasoline is imported for the entire time-series. See text below for details.	Changed CO_2 EF for gasoline

Major revisions in the energy balance have been done for natural gas allocated to the categories 1.A.2 – Manufacturing industries and construction and 1.A.4 – Other sectors for the years 2000-2014. In Luxembourg's previous submissions there was a relatively large difference (around 5%) between the reference approach and the sectoral approach for natural gas allocated to 1.A.2.f – Non-metallic minerals. Indeed, the amount of natural gas allocated to 1.A.2.f – Non-metallic minerals in the national energy balance was significantly lower than the amount determined by a bottom-up approach based on ETS data. The same situation was observed for other sub-sectors, such as the iron and steel industry. The reason for these differences was the following: the physical amounts of natural gas allocated to the different industry sectors in the national energy balance are based on company surveys inquiring the financial expenses for energy consumption. These

[94] Komobile, FVT: Aktualisierung der Zeitreihen zum Kraftstoff-export und der Emissionen von klimarelevanten Gasen und Luftschadstoffen des Verkehrssektors in Luxemburg von 1990 - 2015, Endbericht, 2017, Graz, Luxemburg

financial amounts are then converted into physical amounts by applying a sector-specific standardized energy price. However, if the companies buy their energy at a much lower price than assumed by the national statistics institute, then the physical amount attributed to these companies is too low, which has been the case here for the glass industry. During discussions the inventory team had with the national statistics institute, this problem was acknowledged, and a solution has been developed for allocating the natural gas amounts consumed by the industry in a more realistic way by taking into account ETS declarations. This resulted in an important recalculation of natural gas activity data in the sectors 1.A.2 – Manufacturing industries and construction and 1.A.4 – Other sectors for the years 2000-2014.

Following a recommendation by the ERT (during the UNFCCC centralized review in September 2016), the country-specific CO_2 emission factor for motor gasoline was changed from a fixed value of 72'000 kg CO_2/TJ to a country-specific emission factor based on a weighted average of the EFs of the countries from where motor gasoline ins imported (i.e. Belgium (major import country), Netherlands and Germany) for the entire time-series (Table 3-5). In comparison to the previous submission, the CO_2 emission factor, and hence CO_2 emissions from gasoline, have decreased by 0.7-1.4% (average: - 1.2%) over the entire time series. A study on the carbon-content of motor gasoline samples sold at Luxembourg's petrol stations is currently under way, in order to confirm the new country-specific EF. The categories affected by this revision are 1.A.2.g.vii Manufacturing Industries and Construction – Off-road vehicles and other machinery, 1.A.3.b Road Transportation, 1.A.3.d Navigation, and 1.A.4.b Other Sectors -Residential.

3.2.7.12 Category-specific planned improvements including those in response to the review process

Taking into account the potential contribution of identified improvements in the total GHG emissions and the corresponding resources needed to make these improvements effective, developments presented in Table 3-54 will be explored.

Table 3-54 – Planned improvements for category *1A2– Manufacturing Industries and Construction.*

GHG source & sink category	Planned improvement
1A2	No further improvements planned

3.2.8 Transport (1.A.3)

3.2.8.1 Source category description

This section describes GHG emissio ns resulting from fuel combustion activities in the transport sector.

The 2017 GHG inventory includes emissions from IPCC sub-categories *1A3a – Domestic aviation*, *1A3b – Road Transportation*, *1A3c – Railways* and *1A3d– Domestic Navigation*. This submission does not record any GHG emissions for the IPCC sub-category *1A3e – Other Transportation*.

In 2015, this source category was responsible for 64.44% of GHG emissions from fuel combustion activities (this share was only 25.23% in 1990) and represented 52.93% of the national total GHG emissions excluding LULUCF (coming from 20.30% in 1990). Compared to 2014, emissions decreased by 6.96% and compared to 1990 they increased by 120.25%.

Table 3-55 summarizes GHG emissions for IPCC Sub-category 1A3.

Table 3-55 – GHG emission trends in CO_2e for IPCC sub-category 1A3 – Transport: 1990-2015

1A3 - Transport *GHG emissions by source & sink category (Gg)*												
Year	1A3a - Civil Aviation				1A3b - Road Transportation				1A3c - Railways			
	Total $CO_{2\,eq}$	CO_2	CH_4	N_2O	Total $CO_{2\,eq}$	CO_2	CH_4	N_2O	Total $CO_{2\,eq}$	CO_2	CH_4	N_2O
1990	0.22	*0.21*	*0.000002*	*0.00001*	2 555.71	*2 529.81*	*0.43*	*0.05*	27.33	*0.001*	*0.001*	*0.009*
1991	0.33	*0.33*	*0.000002*	*0.00001*	3 143.25	*3 112.14*	*0.47*	*0.07*	27.34	*0.001*	*0.001*	*0.009*
1992	0.46	*0.46*	*0.000003*	*0.00001*	3 419.20	*3 384.91*	*0.43*	*0.08*	27.35	*0.001*	*0.001*	*0.009*
1993	0.60	*0.60*	*0.000004*	*0.00002*	3 468.60	*3 433.35*	*0.38*	*0.09*	27.34	*0.001*	*0.001*	*0.009*
1994	0.71	*0.70*	*0.000005*	*0.00002*	3 524.88	*3 487.71*	*0.34*	*0.10*	26.55	*0.001*	*0.001*	*0.008*
1995	0.77	*0.76*	*0.000005*	*0.00002*	3 289.93	*3 254.45*	*0.29*	*0.09*	21.50	*0.001*	*0.001*	*0.007*
1996	0.78	*0.78*	*0.000006*	*0.00002*	3 396.86	*3 361.08*	*0.27*	*0.10*	24.04	*0.001*	*0.001*	*0.008*
1997	0.79	*0.79*	*0.000006*	*0.00002*	3 657.50	*3 621.49*	*0.25*	*0.10*	23.64	*0.001*	*0.001*	*0.008*
1998	0.68	*0.68*	*0.000005*	*0.00002*	3 835.39	*3 800.44*	*0.23*	*0.10*	23.66	*0.001*	*0.001*	*0.008*
1999	0.70	*0.69*	*0.000005*	*0.00002*	4 158.22	*4 123.39*	*0.21*	*0.10*	23.67	*0.001*	*0.001*	*0.008*
2000	0.67	*0.66*	*0.000005*	*0.00002*	4 792.31	*4 756.57*	*0.20*	*0.10*	23.42	*0.001*	*0.001*	*0.008*
2001	0.66	*0.65*	*0.000005*	*0.00002*	5 035.54	*5 000.94*	*0.19*	*0.10*	25.25	*0.001*	*0.001*	*0.008*
2002	0.61	*0.61*	*0.000004*	*0.00002*	5 225.84	*5 192.81*	*0.17*	*0.10*	22.32	*0.001*	*0.001*	*0.007*
2003	0.71	*0.71*	*0.000005*	*0.00002*	5 778.00	*5 744.94*	*0.16*	*0.10*	19.45	*0.001*	*0.001*	*0.006*
2004	0.62	*0.62*	*0.000004*	*0.00002*	6 738.00	*6 704.52*	*0.15*	*0.10*	15.45	*0.001*	*0.001*	*0.005*
2005	0.62	*0.61*	*0.000004*	*0.00002*	7 122.06	*7 088.41*	*0.13*	*0.10*	9.79	*0.000*	*0.000*	*0.003*
2006	0.53	*0.52*	*0.000004*	*0.00001*	6 807.46	*6 773.87*	*0.11*	*0.10*	7.29	*0.000*	*0.000*	*0.002*
2007	0.56	*0.55*	*0.000004*	*0.00002*	6 528.27	*6 491.22*	*0.10*	*0.12*	10.07	*0.000*	*0.000*	*0.003*
2008	0.53	*0.53*	*0.000004*	*0.00002*	6 635.45	*6 593.34*	*0.09*	*0.13*	11.54	*0.000*	*0.000*	*0.003*
2009	0.55	*0.54*	*0.000004*	*0.00002*	6 113.22	*6 071.39*	*0.07*	*0.13*	11.06	*0.000*	*0.000*	*0.003*
2010	0.54	*0.54*	*0.000004*	*0.00002*	6 471.75	*6 424.85*	*0.07*	*0.15*	11.88	*0.000*	*0.000*	*0.003*
2011	0.57	*0.57*	*0.000004*	*0.00002*	6 858.89	*6 806.12*	*0.06*	*0.17*	11.83	*0.000*	*0.000*	*0.003*
2012	0.50	*0.49*	*0.000004*	*0.00001*	6 542.41	*6 490.20*	*0.06*	*0.17*	10.71	*0.000*	*0.000*	*0.003*
2013	0.48	*0.47*	*0.000003*	*0.00001*	6 406.33	*6 353.31*	*0.05*	*0.17*	9.19	*0.000*	*0.000*	*0.002*
2014	0.51	*0.50*	*0.000004*	*0.00001*	6 106.22	*6 054.09*	*0.05*	*0.17*	10.39	*0.000*	*0.000*	*0.002*
2015	0.61	*0.60*	*0.000004*	*0.00002*	5 684.11	*5 634.38*	*0.04*	*0.16*	7.03	*0.000*	*0.000*	*0.002*
Trend 1990-2015	*181.21%*	*181.21%*	*181.21%*	*181.21%*	*122.41%*	*122.72%*	*-90.22%*	*221.80%*	*-74.29%*	*-88.41%*	*-88.41%*	*-81.90%*

	1A3 - Transport							
	GHG emissions by source & sink category (Gg)							
Year	**1A3d - Navigation**				**1A3 - Transport**			
	Total $CO_{2\,eq}$	***CO_2***	***CH_4***	***N_2O***	**Total $CO_{2\,eq}$**	***CO_2***	***CH_4***	***N_2O***
1990	1.41	*1.30*	*0.0003*	*0.00034*	2 584.67	*2 531.32*	*0.43*	*0.06*
1991	1.53	*1.41*	*0.0004*	*0.00036*	3 172.45	*3 113.88*	*0.47*	*0.07*
1992	1.46	*1.35*	*0.0004*	*0.00034*	3 448.48	*3 386.72*	*0.44*	*0.09*
1993	1.53	*1.41*	*0.0004*	*0.00036*	3 498.07	*3 435.35*	*0.38*	*0.10*
1994	1.45	*1.34*	*0.0004*	*0.00035*	3 553.59	*3 489.75*	*0.34*	*0.11*
1995	1.26	*1.16*	*0.0003*	*0.00031*	3 313.45	*3 256.37*	*0.29*	*0.10*
1996	1.27	*1.17*	*0.0003*	*0.00031*	3 422.95	*3 363.02*	*0.27*	*0.11*
1997	1.30	*1.20*	*0.0003*	*0.00033*	3 683.24	*3 623.47*	*0.25*	*0.11*
1998	1.26	*1.16*	*0.0003*	*0.00032*	3 860.99	*3 802.27*	*0.23*	*0.11*
1999	1.40	*1.28*	*0.0003*	*0.00037*	4 183.98	*4 125.36*	*0.21*	*0.11*
2000	1.23	*1.13*	*0.0002*	*0.00034*	4 817.63	*4 758.36*	*0.21*	*0.11*
2001	1.38	*1.26*	*0.0003*	*0.00038*	5 062.83	*5 002.86*	*0.19*	*0.11*
2002	1.51	*1.38*	*0.0003*	*0.00042*	5 250.27	*5 194.80*	*0.17*	*0.10*
2003	1.58	*1.44*	*0.0003*	*0.00043*	5 799.74	*5 747.09*	*0.16*	*0.10*
2004	1.46	*1.34*	*0.0002*	*0.00040*	6 755.54	*6 706.47*	*0.15*	*0.10*
2005	1.55	*1.42*	*0.0002*	*0.00042*	7 134.02	*7 090.44*	*0.13*	*0.11*
2006	1.43	*1.31*	*0.0002*	*0.00037*	6 816.70	*6 775.71*	*0.11*	*0.11*
2007	1.44	*1.32*	*0.0002*	*0.00037*	6 540.34	*6 493.09*	*0.10*	*0.12*
2008	1.61	*1.48*	*0.0002*	*0.00041*	6 649.12	*6 595.35*	*0.09*	*0.14*
2009	1.33	*1.23*	*0.0002*	*0.00033*	6 126.16	*6 073.16*	*0.08*	*0.14*
2010	1.45	*1.35*	*0.0002*	*0.00035*	6 485.63	*6 426.73*	*0.07*	*0.16*
2011	1.37	*1.26*	*0.0001*	*0.00033*	6 872.65	*6 807.95*	*0.06*	*0.18*
2012	1.36	*1.26*	*0.0001*	*0.00032*	6 554.98	*6 491.96*	*0.06*	*0.17*
2013	1.18	*1.10*	*0.0001*	*0.00026*	6 417.17	*6 354.89*	*0.05*	*0.18*
2014	1.25	*1.17*	*0.0001*	*0.00027*	6 118.37	*6 055.76*	*0.05*	*0.17*
2015	1.09	*1.02*	*0.0001*	*0.00023*	5 692.83	*5 636.00*	*0.04*	*0.17*
Trend 1990-2015	-22.48%	*-21.46%*	*-67.57%*	*-31.99%*	120.25%	*122.65%*	*-90.20%*	*176.33%*

Notes:

CH_4 emissions are converted in CO_2e by multiplying the emissions by 25, *i.e.* the global warming potential (*GWP*) value for methane based on the effects of GHG over a 100-year time horizon.

N_2O emissions are converted in CO_2e by multiplying the emissions by 298, *i.e.* the global warming potential (*GWP*) value for nitrous oxide based on the effects of GHG over a 100-year time horizon.

3.2.8.2 Domestic aviation (1A3a)

3.2.8.2.1 Source category description

In Luxembourg, domestic aviation, excluding international flights, is a very small activity. There is only one airport for commercial aviation in Luxembourg operated by lux-Airport (Findel). Therefore, all commercial flights, either inbound or outbound, are international flights. For this reason, emissions of kerosene consumption are not included in the national total of Luxembourg, but under international bunkers – aviation, as a memo item. However, private flights with Luxembourg as a start and return point are considered as domestic flights. These are mainly leisure or emergency (medical, police) flights made with small-sized propeller planes or helicopters using aviation gasoline.

In 2015, domestic aviation fuel consumption was responsible for 0.007% of GHG emissions from fuel combustion activities (0.002% in 1990) and represented 0.006% of the national total GHG emissions in CO_2e, excluding LULUCF (0.002% in 1990). Compared to 2014, emissions increased by 20.26%, and compared to 1990 they increased by 181.21%. In absolute terms, *1A3a* emitted 0.61 Gg CO_2e in 2015.

Fuel consumption emissions from domestic aviation are not a key source.

3.2.8.2.2 Methodological issues & time-series consistency

3.2.8.2.2.1 Activity data

There is only one company selling aviation fuels in Luxembourg: Luxfuel S.A.. Activity data for aviation gasoline is obtained directly from this company.

For aviation gasoline, a country-specific NCV (obtained directly from the sole vendor, Luxfuel S.A.) of 43.5 GJ/t aviation gasoline has been applied for converting activity data.

Expert judgement has been made for determining the share of aviation gasoline that is being exported – outbound flights - and the share that is addressed to the domestic consumption – inbound flights. Based on information obtained from the airport authorities, and from the aviation sport clubs registered in Luxembourg, it can be assumed that 90% of aviation gasoline sales are directed towards domestic flights.

3.2.8.2.2.2 Methodological choices

The 2006 IPCC Guidelines Tier 1 approach has been applied for domestic fights. As it is assumed that 90% of aviation gasoline sales are directed towards domestic flights, the emissions of the remaining 10% (international flights) have been accounted for under emissions from international bunker fuels – aviation. Please also refer to section 3.2.2.1 were more details on the split between domestic aviation and international aviation are described.

3.2.8.2.2.3 Emission factors

Default CO_2, CH_4 and N_2O emission factors for aviation gasoline, from the 2006 IPCC Guidelines, were used to calculate the corresponding emissions.

Activity data and emission factors for IPCC sub-category *1A3a – Domestic aviation* are listed in

Table 3-56.

The time-series are considered to be consistent, although the split between domestic and international flights - combusting aviation gasoline - is kept constant over the entire time-series due to a lack of specific annual information.

Table 3-56– Activity data and emission factors for IPCC sub-category 1A3a – Domestic aviation: 1990-2015

1A3a - Civil Aviation *Aviation Gasoline*								
Year	**Activity (GJ)**	**Emission Factors (kg/TJ)**						
		CO_2	***type***	***CH_4***	***type***	***N_2O***	***type***	***source***
1990	3 069	*70 000*	*D*	*0.50*	*D*	*2.00*	*D*	*2006 IPCC GL*
1991	4 662	*70 000*	*D*	*0.50*	*D*	*2.00*	*D*	*2006 IPCC GL*
1992	6 579	*70 000*	*D*	*0.50*	*D*	*2.00*	*D*	*2006 IPCC GL*
1993	8 514	*70 000*	*D*	*0.50*	*D*	*2.00*	*D*	*2006 IPCC GL*
1994	10 071	*70 000*	*D*	*0.50*	*D*	*2.00*	*D*	*2006 IPCC GL*
1995	10 845	*70 000*	*D*	*0.50*	*D*	*2.00*	*D*	*2006 IPCC GL*
1996	11 078	*70 000*	*D*	*0.50*	*D*	*2.00*	*D*	*2006 IPCC GL*
1997	11 232	*70 000*	*D*	*0.50*	*D*	*2.00*	*D*	*2006 IPCC GL*
1998	9 667	*70 000*	*D*	*0.50*	*D*	*2.00*	*D*	*2006 IPCC GL*
1999	9 887	*70 000*	*D*	*0.50*	*D*	*2.00*	*D*	*2006 IPCC GL*
2000	9 418	*70 000*	*D*	*0.50*	*D*	*2.00*	*D*	*2006 IPCC GL*
2001	9 354	*70 000*	*D*	*0.50*	*D*	*2.00*	*D*	*2006 IPCC GL*
2002	8 670	*70 000*	*D*	*0.50*	*D*	*2.00*	*D*	*2006 IPCC GL*
2003	10 095	*70 000*	*D*	*0.50*	*D*	*2.00*	*D*	*2006 IPCC GL*
2004	8 850	*70 000*	*D*	*0.50*	*D*	*2.00*	*D*	*2006 IPCC GL*
2005	8 768	*70 000*	*D*	*0.50*	*D*	*2.00*	*D*	*2006 IPCC GL*
2006	7 466	*70 000*	*D*	*0.50*	*D*	*2.00*	*D*	*2006 IPCC GL*
2007	7 904	*70 000*	*D*	*0.50*	*D*	*2.00*	*D*	*2006 IPCC GL*
2008	7 576	*70 000*	*D*	*0.50*	*D*	*2.00*	*D*	*2006 IPCC GL*
2009	7 739	*70 000*	*D*	*0.50*	*D*	*2.00*	*D*	*2006 IPCC GL*
2010	7 646	*70 000*	*D*	*0.50*	*D*	*2.00*	*D*	*2006 IPCC GL*
2011	8 120	*70 000*	*D*	*0.50*	*D*	*2.00*	*D*	*2006 IPCC GL*
2012	7 059	*70 000*	*D*	*0.50*	*D*	*2.00*	*D*	*2006 IPCC GL*
2013	6 749	*70 000*	*D*	*0.50*	*D*	*2.00*	*D*	*2006 IPCC GL*
2014	7 176	*70 000*	*D*	*0.50*	*D*	*2.00*	*D*	*2006 IPCC GL*
2015	8 630	*70 000*	*D*	*0.50*	*D*	*2.00*	*D*	*2006 IPCC GL*
Trend 1990-2015	*181.21%*	*0.00%*		*0.00%*		*0.00%*		

Source: Environment Agency

3.2.8.3 Road Transportation (1A3b)

3.2.8.3.1 Source category description

In 2015, road transportation was responsible for 64.34% of GHG emissions from fuel combustion activities (this share was only 24.95% in 1990) and represented 52.85% of the national total GHG emissions excluding LULUCF (20.08% in 1990). In absolute terms, GHG emissions from road transportation reached 5684 Gg CO_2e in 2015. Compared to 2014, GHG emissions decreased by 6.91%.

With 46.23% of the total GHG emissions from Luxembourg, road transportation (diesel oil) is the largest key category in 2015. Regarding CO_2, sub-category 1A3b has been a key category for both diesel oil and gasoline without interruption since 1990.

Emissions from road transportation, as reported in the CRF tables, are shown in Table 3-57.

Table 3-57 – Activity data, emission, and implied emission factor trends of IPCC sub-category 1A3b – Road Transportation: 1990-2015

1A3b - Road Transportation
Activity Data, Emissions and Implied Emission Factors

Year	Activity (GJ)					Emissions (Gg)				Implied Emission Factors (kg/TJ)		
	Total (excl. biomass)	*Gasoline (blended)*	*Diesel (blended)*	*LPG*	*Biomass*	Total $CO_{2\,eq}$	*CO_2 (excl. biomass)*	*CH_4 (incl. biomass)*	*N_2O (incl. biomass)*	*CO_2 (excl. biomass)*	*CH_4 (incl. biomass)*	*N_2O (incl. biomass)*
1990	34 950 218	17 663 486	17 112 391	174 340	NO	2 555.71	*2 529.81*	*0.43*	*0.05*	*72 383*	*12*	*1*
1991	42 938 305	20 717 627	22 038 151	182 528	NO	3 143.25	*3 112.14*	*0.47*	*0.07*	*72 479*	*11*	*2*
1992	46 614 793	22 417 111	24 047 446	150 236	NO	3 419.20	*3 384.91*	*0.43*	*0.08*	*72 614*	*9*	*2*
1993	47 294 934	22 532 289	24 602 289	160 356	NO	3 468.60	*3 433.35*	*0.38*	*0.09*	*72 594*	*8*	*2*
1994	48 078 551	23 372 993	24 546 214	159 344	NO	3 524.88	*3 487.71*	*0.34*	*0.10*	*72 542*	*7*	*2*
1995	44 887 293	22 046 032	22 687 712	153 548	NO	3 289.93	*3 254.45*	*0.29*	*0.09*	*72 503*	*6*	*2*
1996	46 345 206	22 354 776	23 875 201	115 230	NO	3 396.86	*3 361.08*	*0.27*	*0.10*	*72 523*	*6*	*2*
1997	49 911 918	23 253 271	26 605 379	53 268	NO	3 657.50	*3 621.49*	*0.25*	*0.10*	*72 558*	*5*	*2*
1998	52 341 502	23 376 245	28 836 365	128 892	NO	3 835.39	*3 800.44*	*0.23*	*0.10*	*72 608*	*4*	*2*
1999	56 749 106	24 173 920	32 455 862	119 324	NO	4 158.22	*4 123.39*	*0.21*	*0.10*	*72 660*	*4*	*2*
2000	65 369 047	24 964 107	40 313 031	91 908	NO	4 792.31	*4 756.57*	*0.20*	*0.10*	*72 765*	*3*	*2*
2001	68 649 628	24 538 589	43 992 818	118 220	NO	5 035.54	*5 000.94*	*0.19*	*0.10*	*72 847*	*3*	*1*
2002	71 230 571	23 918 281	47 195 036	117 254	NO	5 225.84	*5 192.81*	*0.17*	*0.10*	*72 901*	*2*	*1*
2003	78 720 260	24 344 139	54 282 281	93 840	NO	5 778.00	*5 744.94*	*0.16*	*0.10*	*72 979*	*2*	*1*
2004	91 686 426	23 603 163	68 002 947	80 316	IE	6 738.00	*6 704.52*	*0.15*	*0.10*	*73 124*	*2*	*1*
2005	96 783 864	21 492 936	75 233 658	57 270	IE	7 122.06	*7 088.41*	*0.13*	*0.10*	*73 240*	*1*	*1*
2006	92 433 115	19 309 525	73 059 880	63 710	IE	6 807.46	*6 773.87*	*0.11*	*0.10*	*73 284*	*1*	*1*
2007	90 364 012	18 540 629	71 760 915	62 468	IE	6 528.27	*6 491.22*	*0.10*	*0.12*	*71 834*	*1*	*1*
2008	91 660 521	17 630 270	73 957 249	73 002	IE	6 635.45	*6 593.34*	*0.09*	*0.13*	*71 932*	*1*	*1*
2009	84 489 788	16 233 735	68 193 984	62 069	IE	6 113.22	*6 071.39*	*0.07*	*0.13*	*71 859*	*1*	*2*
2010	89 250 997	15 092 572	74 096 238	62 187	IE	6 471.75	*6 424.85*	*0.07*	*0.15*	*71 986*	*1*	*2*
2011	94 860 701	15 664 545	79 167 440	28 717	IE	6 858.89	*6 806.12*	*0.06*	*0.17*	*71 749*	*1*	*2*
2012	90 433 667	15 028 638	75 326 579	78 450	IE	6 542.41	*6 490.20*	*0.06*	*0.17*	*71 768*	*1*	*2*
2013	88 680 624	13 652 494	74 974 350	53 780	IE	6 406.33	*6 353.31*	*0.05*	*0.17*	*71 643*	*1*	*2*
2014	85 287 563	13 222 433	72 003 101	62 029	IE	6 106.22	*6 054.09*	*0.05*	*0.17*	*70 984*	*1*	*2*
2015	80 255 921	12 540 649	67 684 159	31 113	IE	5 684.11	*5 634.38*	*0.04*	*0.16*	*70 205*	*1*	*2*
Trend 1990-2015	*129.63%*	*-29.00%*	*295.53%*	*-82.15%*	*NA*	*122.41%*	*122.72%*	*-90.22%*	*221.80%*	*-3.01%*	*-95.74%*	*40.14%*
Trend 2014-2015	*-5.90%*	*-5.16%*	*-6.00%*	*-49.84%*	*NA*	*-6.91%*	*-6.93%*	*-9.54%*	*-4.49%*	*-1.10%*	*-3.87%*	*1.50%*

Source: Environment Agency

As already explained in previous sections of the NIR (please refer to chapter 2 on emission trends), Luxembourg's situation regarding emissions from *1A3b - Road Transportation* is quite unique, due to the high share of fuel export in the vehicles' tank.

Figure 3-7 shows the evolution of fuel sold (*i.e.* blended fuel) in Luxembourg. Diesel oil is by far the most sold fuel, although during recent years its consumption seems to decline slightly.

Figure 3-7 – Fuel sold trends - indexes - for 1A3b – Road Transportation by fuel type: 1990-2015

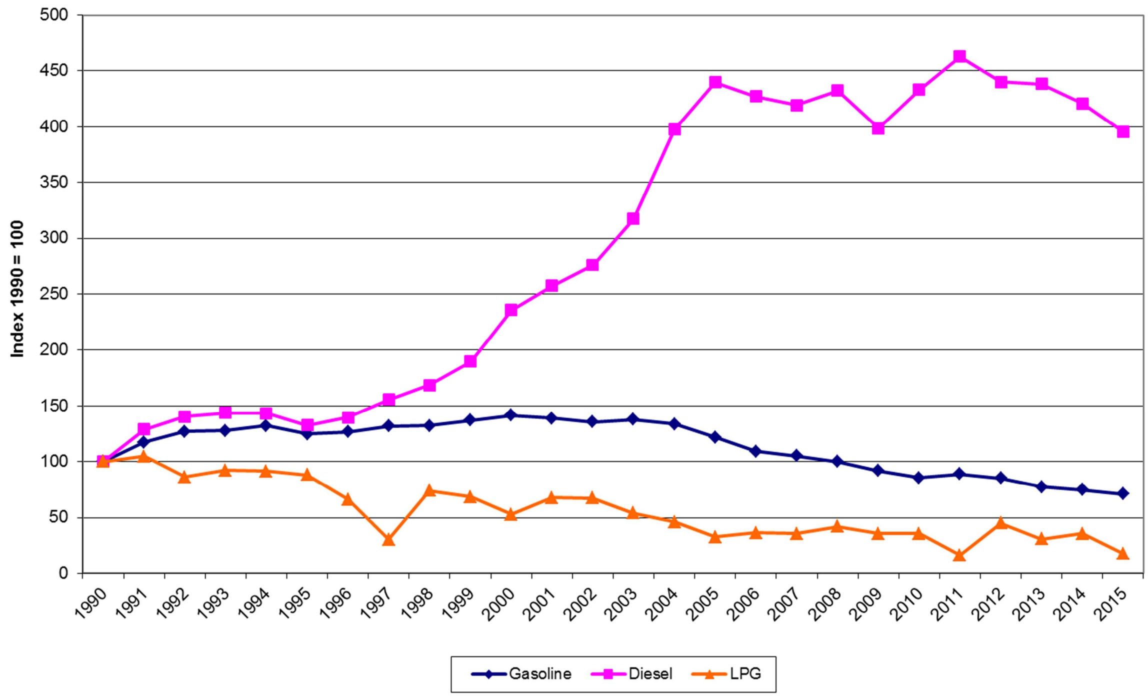


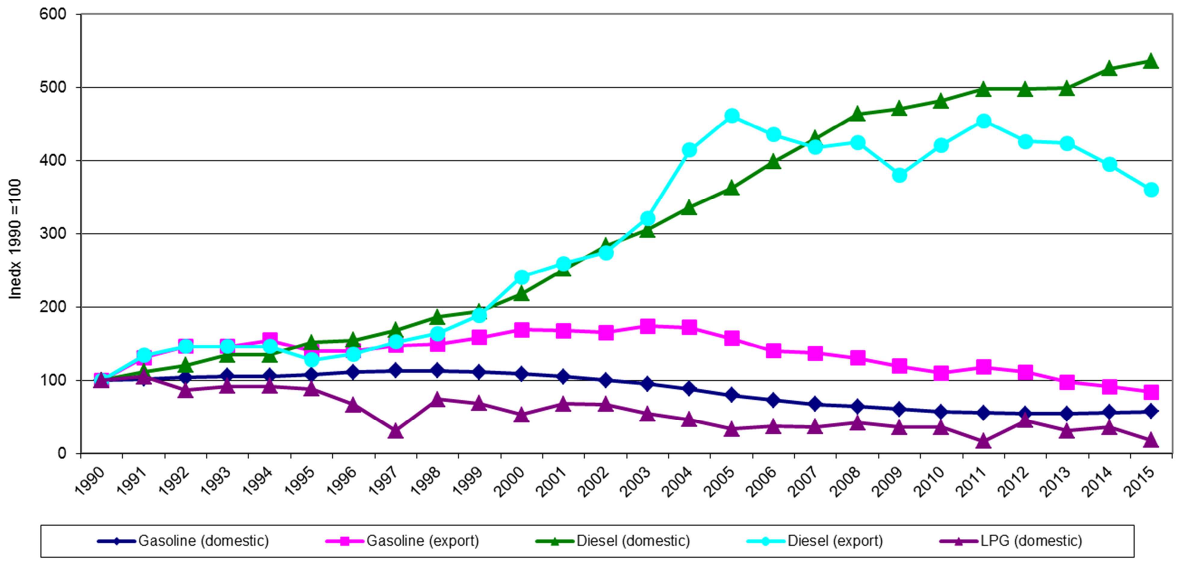
Table 3-58 and Figure 3-8 detail the quantities of blended fuel sold to the domestic fleet and the amount of fuel exported.

Table 3-58 – Total fuel sold for road transport – inland consumption and road fuel export: 1990-2015

1A3b - Road Transportation *Implied Emission Factors (kg/TJ)*												
Year	Gasoline			Diesel			LPG			Biomass		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
1990	*71 014*	*23.17*	*2.35*	*75 325*	*1.10*	*0.53*	*65 068*	*19.37*	*2.34*	*NA*	*NA*	*NA*
1991	*71 050*	*21.31*	*2.52*	*75 153*	*1.02*	*0.58*	*65 099*	*17.84*	*2.51*	*NA*	*NA*	*NA*
1992	*71 275*	*18.20*	*2.83*	*75 170*	*0.99*	*0.63*	*65 002*	*15.19*	*2.83*	*NA*	*NA*	*NA*
1993	*71 256*	*15.59*	*3.11*	*75 282*	*0.99*	*0.67*	*64 933*	*12.96*	*3.10*	*NA*	*NA*	*NA*
1994	*71 223*	*13.44*	*3.34*	*75 413*	*0.99*	*0.73*	*64 933*	*11.12*	*3.34*	*NA*	*NA*	*NA*
1995	*71 178*	*12.00*	*3.50*	*75 701*	*0.98*	*0.78*	*64 933*	*9.88*	*3.50*	*NA*	*NA*	*NA*
1996	*71 143*	*10.87*	*3.52*	*75 751*	*0.94*	*0.81*	*64 933*	*8.91*	*3.51*	*NA*	*NA*	*NA*
1997	*71 096*	*9.79*	*3.36*	*75 749*	*0.87*	*0.83*	*64 933*	*8.00*	*3.36*	*NA*	*NA*	*NA*
1998	*71 110*	*8.77*	*3.12*	*75 789*	*0.80*	*0.88*	*64 953*	*7.13*	*3.11*	*NA*	*NA*	*NA*
1999	*71 093*	*7.84*	*2.87*	*75 834*	*0.74*	*0.92*	*65 264*	*6.36*	*2.86*	*NA*	*NA*	*NA*
2000	*71 078*	*7.11*	*2.64*	*75 632*	*0.66*	*0.93*	*64 943*	*5.76*	*2.63*	*NA*	*NA*	*NA*
2001	*71 133*	*6.54*	*2.40*	*75 596*	*0.60*	*0.96*	*64 942*	*5.27*	*2.39*	*NA*	*NA*	*NA*
2002	*71 119*	*6.01*	*2.14*	*75 597*	*0.56*	*0.98*	*64 957*	*4.82*	*2.12*	*NA*	*NA*	*NA*
2003	*71 081*	*5.52*	*1.88*	*75 446*	*0.52*	*0.97*	*64 976*	*4.41*	*1.87*	*NA*	*NA*	*NA*
2004	*71 066*	*5.15*	*1.65*	*75 179*	*0.48*	*0.90*	*64 949*	*4.06*	*1.64*	*NA*	*NA*	*NA*
2005	*71 084*	*4.80*	*1.44*	*75 120*	*0.42*	*0.95*	*64 952*	*3.74*	*1.43*	*NA*	*NA*	*NA*
2006	*71 145*	*4.51*	*1.26*	*75 214*	*0.35*	*1.10*	*64 956*	*3.46*	*1.25*	*NA*	*NA*	*NA*
2007	*70 995*	*4.23*	*1.11*	*73 509*	*0.29*	*1.36*	*64 933*	*3.22*	*1.10*	*NA*	*NA*	*NA*
2008	*71 170*	*3.95*	*0.95*	*73 603*	*0.24*	*1.62*	*64 933*	*2.96*	*0.94*	*NA*	*NA*	*NA*
2009	*71 016*	*3.72*	*0.83*	*73 684*	*0.21*	*1.81*	*64 957*	*2.74*	*0.82*	*NA*	*NA*	*NA*
2010	*70 949*	*3.55*	*0.73*	*73 748*	*0.18*	*1.94*	*64 933*	*2.56*	*0.72*	*NA*	*NA*	*NA*
2011	*70 291*	*3.36*	*0.66*	*73 554*	*0.15*	*2.08*	*64 933*	*2.42*	*0.65*	*NA*	*NA*	*NA*
2012	*70 831*	*3.13*	*0.57*	*73 596*	*0.13*	*2.20*	*64 933*	*2.21*	*0.56*	*NA*	*NA*	*NA*
2013	*71 285*	*3.00*	*0.51*	*73 383*	*0.12*	*2.27*	*64 933*	*2.06*	*0.50*	*NA*	*NA*	*NA*
2014	*71 058*	*2.95*	*0.49*	*72 789*	*0.11*	*2.34*	*64 933*	*2.02*	*0.48*	*NA*	*NA*	*NA*
2015	*70 483*	*2.85*	*0.46*	*72 138*	*0.10*	*2.39*	*64 933*	*1.93*	*0.45*	*NA*	*NA*	*NA*
Trend 1990-2015	*-0.75%*	*-87.71%*	*-80.50%*	*-4.23%*	*-91.17%*	*352.66%*	*-0.21%*	*-90.01%*	*-80.80%*	*NA*	*NA*	*NA*

<u>Source:</u> Environment Agency

Figure 3-8 – Domestic and exported fuel sold trends - indexes - for 1A3b – Road Transportation by fuel type: 1990-2015



In 2015, as shown in Table 3-59, emissions from road fuel export were more than two times higher than those from the domestic fleet.

Table 3-59 – Domestic and road fuel export emissions for 1A3b - Road Transportation: 1990-2015

1A3b - Road Transportation

CO_2 eq emissions (Gg)

Year	National Total (excl. CO_2 from biomass)	CO_2 from biomass	domestic road fuel emissions (excl. CO_2 from biomass)					road fuel export emissions (excl. CO_2 from biomass)				
			Total	share (%)	*Gasoline*	*Diesel*	*LPG*	Total	share (%)	*Gasoline*	*Diesel*	*LPG*
1990	**2555.71**	**NO**	**862.85**	33.76%	*580.80*	*270.50*	*11.55*	**1692.86**	66.24%	*696.14*	*996.72*	*NO*
1991	**3143.25**	**NO**	**903.28**	28.74%	*588.85*	*302.33*	*12.10*	**2239.97**	71.26%	*909.74*	*1330.23*	*NO*
1992	**3419.20**	**NO**	**939.50**	27.48%	*604.70*	*324.85*	*9.95*	**2479.70**	72.52%	*1022.19*	*1457.51*	*NO*
1993	**3468.60**	**NO**	**987.54**	28.47%	*612.85*	*364.08*	*10.61*	**2481.06**	71.53%	*1022.35*	*1458.71*	*NO*
1994	**3524.88**	**NO**	**989.70**	28.08%	*614.98*	*364.17*	*10.55*	**2535.18**	71.92%	*1080.84*	*1454.34*	*NO*
1995	**3289.93**	**NO**	**1045.77**	31.79%	*625.09*	*410.52*	*10.17*	**2244.16**	68.21%	*973.72*	*1270.44*	*NO*
1996	**3396.86**	**NO**	**1071.21**	31.54%	*644.39*	*419.18*	*7.63*	**2325.65**	68.46%	*975.49*	*1350.17*	*NO*
1997	**3657.50**	**NO**	**1114.49**	30.47%	*655.72*	*455.25*	*3.52*	**2543.01**	69.53%	*1026.48*	*1516.54*	*NO*
1998	**3835.39**	**NO**	**1165.17**	30.38%	*653.03*	*503.62*	*8.51*	**2670.22**	69.62%	*1036.13*	*1634.08*	*NO*
1999	**4158.22**	**NO**	**1177.46**	28.32%	*644.00*	*525.55*	*7.91*	**2980.76**	71.68%	*1100.00*	*1880.76*	*NO*
2000	**4792.31**	**NO**	**1225.36**	25.57%	*628.51*	*590.79*	*6.05*	**3566.95**	74.43%	*1169.95*	*2397.00*	*NO*
2001	**5035.54**	**NO**	**1294.36**	25.70%	*606.05*	*680.53*	*7.78*	**3741.18**	74.30%	*1160.99*	*2580.19*	*NO*
2002	**5225.84**	**NO**	**1351.97**	25.87%	*577.17*	*767.10*	*7.70*	**3873.86**	74.13%	*1142.68*	*2731.18*	*NO*
2003	**5778.00**	**NO**	**1380.06**	23.88%	*546.62*	*827.28*	*6.16*	**4397.94**	76.12%	*1200.78*	*3197.16*	*NO*
2004	**6738.00**	**1.45**	**1422.61**	21.11%	*506.71*	*910.63*	*5.26*	**5315.39**	78.89%	*1185.30*	*4130.10*	*NO*
2005	**7122.06**	**1.51**	**1442.80**	20.26%	*455.94*	*983.11*	*3.75*	**5679.26**	79.74%	*1083.69*	*4595.58*	*NO*
2006	**6807.46**	**1.42**	**1502.04**	22.06%	*417.72*	*1080.16*	*4.17*	**5305.42**	77.94%	*965.50*	*4339.92*	*NO*
2007	**6528.27**	**131.22**	**1527.06**	23.39%	*384.81*	*1138.16*	*4.08*	**5001.22**	76.61%	*939.55*	*4061.67*	*NO*
2008	**6635.45**	**130.59**	**1600.28**	24.12%	*367.15*	*1228.37*	*4.77*	**5035.17**	75.88%	*894.35*	*4140.82*	*NO*
2009	**6113.22**	**123.49**	**1594.82**	26.09%	*343.24*	*1247.52*	*4.05*	**4518.41**	73.91%	*815.13*	*3703.28*	*NO*
2010	**6471.75**	**123.91**	**1606.10**	24.82%	*324.18*	*1277.86*	*4.06*	**4865.64**	75.18%	*751.26*	*4114.38*	*NO*
2011	**6858.89**	**155.20**	**1632.64**	23.80%	*312.86*	*1317.91*	*1.87*	**5226.24**	76.20%	*792.60*	*4433.65*	*NO*
2012	**6542.41**	**143.97**	**1632.35**	24.95%	*309.90*	*1317.35*	*5.11*	**4910.05**	75.05%	*758.34*	*4151.72*	*NO*
2013	**6406.33**	**161.42**	**1627.59**	25.41%	*309.07*	*1315.02*	*3.50*	**4778.73**	74.59%	*667.26*	*4111.47*	*NO*
2014	**6106.22**	**213.20**	**1693.69**	27.74%	*318.93*	*1370.72*	*4.04*	**4412.53**	72.26%	*623.53*	*3789.01*	*NO*
2015	**5684.11**	**262.51**	**1703.20**	29.96%	*320.43*	*1380.74*	*2.03*	**3980.90**	70.04%	*566.07*	*3414.83*	*NO*
Trend 1990-2015	*122.41%*	*NA*	*97.39%*	*-11.25%*	*-44.83%*	*410.44%*	*-82.46%*	*135.16%*	*5.73%*	*-18.68%*	*242.61%*	*NA*
Trend 2014-2015	*-6.91%*	*23.13%*	*0.56%*	*8.03%*	*0.47%*	*0.73%*	*-49.85%*	*-9.78%*	*-3.08%*	*-9.21%*	*-9.88%*	*NA*
Share 1990	*NA*	*NA*	*100.00%*	*0.04%*	*67.31%*	*31.35%*	*1.34%*	*100.00%*	*0.04%*	*41.12%*	*58.88%*	*NA*
Share 2015	*NA*	*NA*	*100.00%*	*0.02%*	*18.81%*	*81.07%*	*0.12%*	*100.00%*	*0.02%*	*14.22%*	*85.78%*	*NA*

Source: Environment Agency

3.2.8.3.2 Methodological issues & time series consistency

3.2.8.3.2.1 Activity data

Table 3-60 and Table 3-61 show the activity data by vehicle category for fuel sold in Luxembourg and fuel used within the country's borders, respectively. The amounts of fuel sold were taken from the national energy balance provided by STATEC, and the share of fuel used in Luxembourg was determined with the method described on page 228.

Table 3-60 – Activity data of 1A3b Road transport – Fuel sold

1 A Mobile Fuel Combustion					
Activity Data by vehicle category (GJ)					
1 A 3 b Road transport - FUEL SOLD					
Year	**Activity Total (incl. biomass)**	**1 A 3 b i** *Passenger cars*	**1 A 3 b ii** *LDV*	**1 A 3 b iii** *HDV and buses*	**1 A 3 b iv** *Mopeds & motorcycles*
1990	34 950 218	21 604 173	476 844	12 835 255	33 945
1991	42 938 305	25 737 809	529 565	16 633 864	37 067
1992	46 614 793	28 057 905	564 308	17 951 523	41 057
1993	47 294 934	28 405 451	628 581	18 212 938	47 965
1994	48 078 551	30 573 215	679 144	16 773 430	52 763
1995	44 887 293	29 129 615	726 595	14 978 300	52 783
1996	46 345 206	29 886 779	764 489	15 639 828	54 111
1997	49 911 918	30 959 605	820 892	18 074 830	56 592
1998	52 341 502	31 954 871	877 912	19 449 340	59 379
1999	56 749 106	33 786 474	988 520	21 912 574	61 538
2000	65 369 047	35 962 883	1 086 979	28 255 084	64 100
2001	68 649 628	36 964 566	1 140 452	30 478 927	65 684
2002	71 230 571	37 540 623	1 201 747	32 419 831	68 370
2003	78 720 260	39 644 090	1 234 327	37 771 039	70 803
2004	91 686 426	40 516 608	1 270 897	49 822 139	76 781
2005	96 783 864	39 166 759	1 320 122	56 218 437	78 545
2006	92 433 115	37 511 175	1 373 618	53 468 076	80 245
2007	90 364 012	38 109 065	1 470 126	50 702 857	81 964
2008	91 660 521	37 818 173	1 536 405	52 222 713	83 231
2009	84 489 788	36 393 109	1 540 715	46 470 974	84 990
2010	89 250 997	34 858 843	1 592 381	52 713 428	86 345
2011	94 860 701	36 504 587	1 669 459	56 597 574	89 081
2012	90 433 667	35 566 125	1 710 074	53 066 877	90 592
2013	88 680 624	33 242 838	1 740 714	53 603 146	93 927
2014	85 287 563	32 809 786	1 826 393	50 554 261	97 124
2015	80 255 921	31 702 292	1 891 667	46 562 040	99 922
Trend 1990-2015	*129.63%*	*46.74%*	*296.71%*	*262.77%*	*194.36%*

Table 3-61 – Activity data of 1A3b Road transport – Fuel used

1 A Mobile Fuel Combustion					
Activity Data by vehicle category (GJ)					
1 A 3 b Road transport - FUEL USED					
Year	Activity Total (incl. biomass)	1 A 3 b i *Passenger cars*	1 A 3 b ii *LDV*	1 A 3 b iii *HDV and buses*	1 A 3 b iv *Mopeds & motorcycles*
1990	11 857 309	9 154 059	476 844	2 192 461	33 945
1991	12 399 771	9 477 318	529 565	2 355 821	37 067
1992	12 860 200	9 848 034	564 308	2 406 801	41 057
1993	13 513 819	10 192 236	628 581	2 645 038	47 965
1994	13 545 384	10 496 606	679 144	2 316 870	52 763
1995	14 308 041	10 859 092	726 595	2 669 572	52 783
1996	14 657 765	11 341 218	764 489	2 497 947	54 111
1997	15 251 291	11 810 517	820 892	2 563 291	56 592
1998	15 948 666	12 339 521	877 912	2 671 853	59 379
1999	16 119 758	12 703 845	988 520	2 365 855	61 538
2000	16 768 127	13 065 773	1 086 979	2 551 275	64 100
2001	17 692 294	13 554 958	1 140 452	2 931 200	65 684
2002	18 465 332	13 884 779	1 201 747	3 310 437	68 370
2003	18 834 497	14 143 768	1 234 327	3 385 599	70 803
2004	19 392 113	14 493 749	1 270 897	3 550 686	76 781
2005	19 633 905	14 629 107	1 320 122	3 606 131	78 545
2006	20 408 643	15 068 754	1 373 618	3 886 026	80 245
2007	21 115 584	15 489 079	1 470 126	4 074 414	81 964
2008	22 089 619	16 170 835	1 536 405	4 299 148	83 231
2009	22 027 608	16 274 581	1 540 715	4 127 322	84 990
2010	22 146 614	16 067 487	1 592 381	4 400 401	86 345
2011	22 582 222	16 232 887	1 669 459	4 590 796	89 081
2012	22 565 718	16 353 884	1 710 074	4 411 168	90 592
2013	22 530 033	16 446 375	1 740 714	4 249 018	93 927
2014	23 652 587	17 046 490	1 826 393	4 682 581	97 124
2015	24 040 807	17 243 108	1 891 667	4 806 110	99 922
Trend 1990-2015	*102.75%*	*88.37%*	*296.71%*	*119.21%*	*194.36%*

Figure 3-9 shows the evolution of the vehicle numbers per category since 1990 (national fleet). The number of diesel-fuelled passenger cars has strongly increased whereas the vehicle numbers in the other categories show a less pronounced rise or even a slight decrease in the case of passenger cars with otto engines. The same trends are observed for the total mileage driven in Luxembourg (Figure 3-10).

Figure 3-9 – Vehicle numbers per category (national fleet).

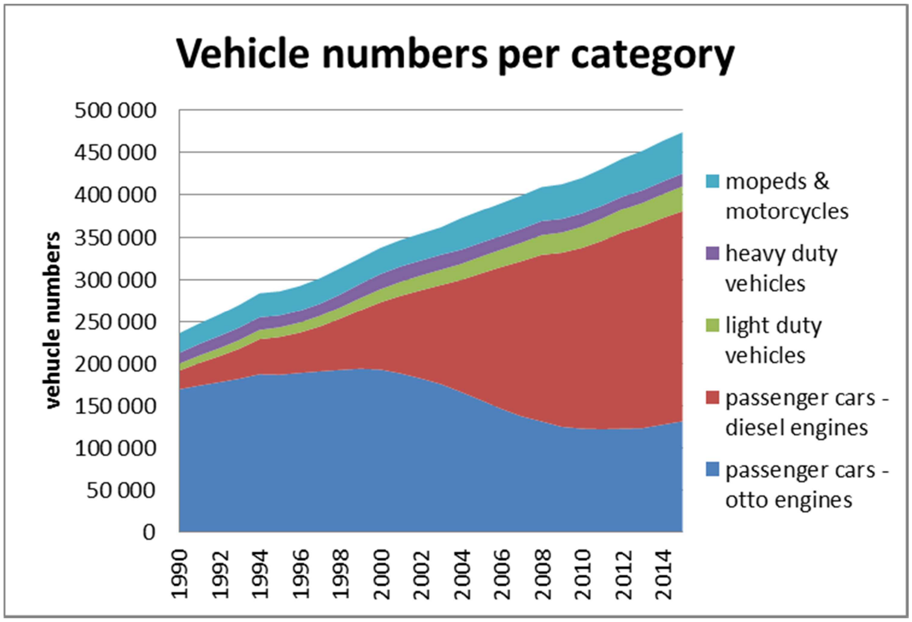


Figure 3-10 – Total mileage in Luxembourg.

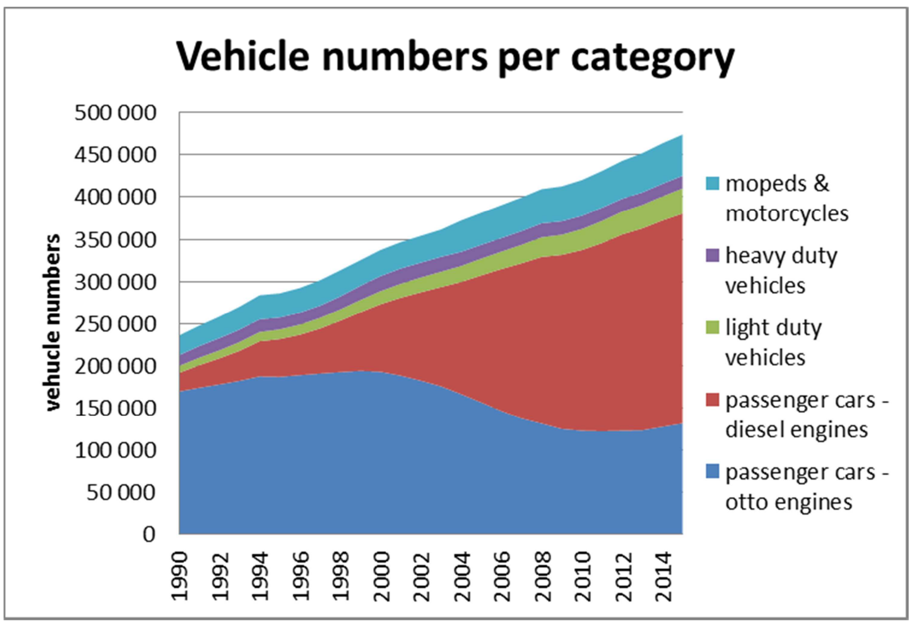
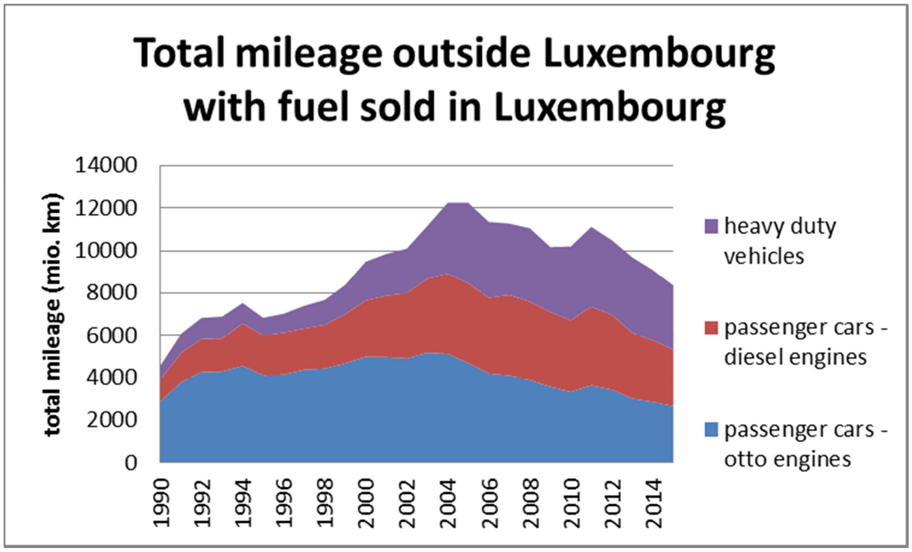


Figure 3-11 shows that the total mileage driven outside Luxembourg with fuel purchased in Luxembourg has approximately doubled since 1990. While the mileage driven with gasoline exported in passenger car tanks has remained relatively stable, the mileage driven with diesel exported from Luxembourg in the tanks of passenger cars and heavy duty vehicles has significantly increased.

Figure 3-11 – Total mileage outside Luxembourg with fuel sold in Luxembourg.



3.2.8.3.2.2 Methodology - The model NEMO and its application to Luxembourg's road transport situation

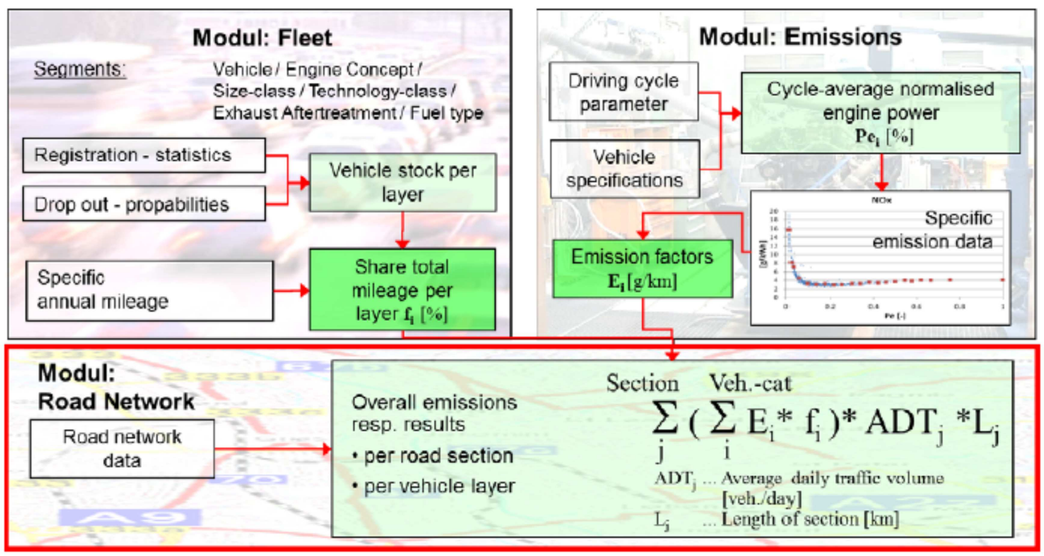
The model NEMO (Network Emission Model) was developed at the Institute for Internal Combustion Engines and Thermodynamics (IVT) at the Graz University of Technology (TUG) as tool for the simulation of traffic related emissions in road networks. Typical applications reach from emission inventories for cities, regions and countries to complex measures like environmental zones or promotion of alternative propulsion systems. An interface to macro scale traffic models, such as VISUM and to air quality modelling is available.

NEMO combines both detailed calculation of the vehicle fleet composition and simulation of emission factors on a vehicle level. NEMO calculates the percentages of different vehicle layers on the overall traffic volume as a function of year and considered road type based on data on vehicle stock, composition of new registrations and vehicle usage. The simulation of the emissions of the different vehicle layers is based on the correlation of the specific engine emission behaviour (emissions in grams per kilowatt-hour engine work) with the cycle average engine power in a normalised format. The calculation of the required engine power is based on average speed and additional kinematic parameters for the description of the cycle dynamics for a given road section. Compared to more detailed instantaneous emission models - which are usually based on simulation in 1Hz time resolution – this simplified approach gives no disadvantage for the modelling of emissions on large street networks as in most of the cases 1Hz data for vehicle operation are not available. An additional benefit of the NEMO simulation approach is the short computing time.

The parameterisation of NEMO is based on data from European in-use measurements which are also used for the Handbook Emission Factors of Road Transport[95]. NEMO is updated regularly according to recent data on emission behaviour and vehicle technologies. All on-road vehicle categories are covered; a tool for the transport sectors rail and inland waterway shipping is also available. NEMO is equipped with a Graphical User Interface which allows for efficient data editing, scenario handling and display of model results.

A crucial point in emission modelling is the characterisation of driving behaviour on the single road sections. For NEMO a method was developed, which allows for automatized derivation of driving behaviour based on a link with common traffic models. These models use the peak hour driving time between knots of the street work as resistance parameter for allocation of traffic volumes to the single road sections. NEMO imports this data together with the parameters of the capacity-restraint functions and calculates the daily average velocity for each road section. Based on functions derived from the driving cycles used in the HBEFA then the kinematic parameters needed for emission simulation (vehicle stop time and average brake deceleration) are assessed.

Figure 3-12– Schematic picture of the model NEMO



NEMO calculates the emissions for all regulated pollutants (NO_x, THC, CO, PM exhaust) for hot vehicle operation. Fuel consumption is simulated based on a slightly extended method which also considers the energy content of the applied fuel type. The emissions of CO_2 and SO_2 are simulated based on fuel consumption and fuel specifications. The non-regulated pollutants N_2O, NH_3 CH_4,

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[95] Handbook emission factors for road transport (HBEFA) http://www.hbefa.net/

NMVOC and C_6H_6 are calculated with an approach similar to the HBEFA 3.2 based on fixed emission factors for certain vehicle categories and driving situations.

Additional influencing mechanisms on the emission output of road traffic implemented in NEMO are:

- Cold start effects for each vehicle class (data and approach compatible to the HBEFA 3.2)
- Influence of mileage and maintenance on the emissions of gasoline vehicles[96]
- Calibration of fuel consumption based on statistics of g/km CO_2 of new registered vehicles in the NEDC type approval and literature on the discrepancies between NEDC and real world CO_2 reduction rates[97]
- Evaporation from gasoline emissions (data and approach compatible to the HBEFA 3.2).

Particle emissions due to vehicle induced abrasion and re-suspension processes ("PM non-exhaust") are taken into account by NEMO in addition to the PM-exhaust emissions. The calculation of the PM non-exhaust emissions is based on the values published in[98].

As already mentioned above, the major part of the fuel sold in Luxembourg is exported inside vehicle tanks. The split of the total fuel into domestic fuel use and exported fuel is thus a key element of the calculation of Luxembourg's total GHG emissions. This split is performed in several steps:

(i) estimation of the domestic fuel consumption with the NEMO model
(ii) calculation of the amount of exported fuel by subtracting the amount obtained in step (i) from the total national fuel consumption obtained from Statec
(iii) the entire amount of exported gasoline is attributed to passenger cars
(iv) the amount of diesel exported by passenger cars is determined by taking into account the result of step (iii) and the shares of gasoline- and diesel-fuelled cars in the trans-border fleet
(v) the amount of diesel exported by heavy duty vehicles is obtained by subtracting the amount of diesel exported by passenger cars from the total amount of exported diesel
(vi) now the mileages of the passenger cars and heavy duty vehicles responsible for the fuel export can be determined based on their fuel consumption

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96 Samaras, Z. (2004). Artemis Subtask 3123: Investigation of the emission degradation of gasoline vehicles, Aristotle University of Thessaloniki - Lab of Applied Thermodynamics

97 Mock P., German J., Bandivadekar A., Riemersma I. (2012), ICCT working paper 2012-02: Discrepancies between type-approval and „real-world" fuel-consumption and CO_2 values

98 Schmidt W., Düring I., Lohmeyer A., (2011) Einbindung des HBEFA 3.1 in das FIS Umwelt und Verkehr sowie Neufassung der Emissionsfaktoren für Aufwirbelung und Abrieb des Straßenverkehrs

(vii) finally the emissions caused by domestic fuel use and exported fuel are calculated separately by NEMO.

In these calculations it is assumed that the composition of the commuting and transiting fleets is identical to the domestic fleet.

The GHG emissions from road transportation were calculated with the NEMO model for the timeseries 1990-2015[99].

The sources of the emission factors used for the emission calculations are given in paragraph 3.2.8.3.2.2.

For biogasoline (ethanol, ETBE) and biodiesel (FAME, HVH, HVP), European CO_2 implied emission factors[100] for gasoline and diesel oil, respectively, were used as emission factors.

For an overview of the implied emission factors for motor gasoline, diesel oil, LPG and liquid biomass please refer to Table 3-62. The CO_2 IEFs for gasoline and diesel result from dividing fossil CO_2 emissions by blended fuel consumptions. This means that in the years where biofuels were used (since 2007 for biogasoline, and since 2004 for biodiesel) the CO_2 IEFs in this table are slightly lower. The changes of CH_4 and N_2O IEFs over time are due to new developments in vehicle technology.

99 Komobile, FVT: Aktualisierung der Zeitreihen zum Kraftstoff-export und der Emissionen von klimarelevanten Gasen und Luftschadstoffen des Verkehrssektors in Luxemburg von 1990 - 2015, Endbericht, 2017, Graz, Luxemburg

100 UNFCCC SAI Report 2008, FCCC/WEB/SAI/2008, Table 1.30, p.66

Table 3-62 – Implied emission factors per fuel type for IPCC sub-category 1A3b – Road Transport: 1990-2015

1A3b - Road Transportation *Implied Emission Factors (kg/TJ)*												
Year	Gasoline (blended)			Diesel (blended)			LPG			Biomass		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
1990	71 014	23.17	2.35	75 325	1.10	0.53	65 068	19.37	2.34	NA	NA	NA
1991	71 050	21.31	2.52	75 153	1.02	0.58	65 099	17.84	2.51	NA	NA	NA
1992	71 275	18.20	2.83	75 170	0.99	0.63	65 002	15.19	2.83	NA	NA	NA
1993	71 256	15.59	3.11	75 282	0.99	0.67	64 933	12.96	3.10	NA	NA	NA
1994	71 223	13.44	3.34	75 413	0.99	0.73	64 933	11.12	3.34	NA	NA	NA
1995	71 178	12.00	3.50	75 701	0.98	0.78	64 933	9.88	3.50	NA	NA	NA
1996	71 143	10.87	3.52	75 751	0.94	0.81	64 933	8.91	3.51	NA	NA	NA
1997	71 096	9.79	3.36	75 749	0.87	0.83	64 933	8.00	3.36	NA	NA	NA
1998	71 110	8.77	3.12	75 789	0.80	0.88	64 953	7.13	3.11	NA	NA	NA
1999	71 093	7.84	2.87	75 834	0.74	0.92	65 264	6.36	2.86	NA	NA	NA
2000	71 078	7.11	2.64	75 632	0.66	0.93	64 943	5.76	2.63	NA	NA	NA
2001	71 133	6.54	2.40	75 596	0.60	0.96	64 942	5.27	2.39	NA	NA	NA
2002	71 119	6.01	2.14	75 597	0.56	0.98	64 957	4.82	2.12	NA	NA	NA
2003	71 081	5.52	1.88	75 446	0.52	0.97	64 976	4.41	1.87	NA	NA	NA
2004	71 066	5.15	1.65	75 179	0.48	0.90	64 949	4.06	1.64	NA	NA	NA
2005	71 084	4.80	1.44	75 120	0.42	0.95	64 952	3.74	1.43	NA	NA	NA
2006	71 145	4.51	1.26	75 214	0.35	1.10	64 956	3.46	1.25	NA	NA	NA
2007	70 995	4.23	1.11	73 509	0.29	1.36	64 933	3.22	1.10	NA	NA	NA
2008	71 170	3.95	0.95	73 603	0.24	1.62	64 933	2.96	0.94	NA	NA	NA
2009	71 016	3.72	0.83	73 684	0.21	1.81	64 957	2.74	0.82	NA	NA	NA
2010	70 949	3.55	0.73	73 748	0.18	1.94	64 933	2.56	0.72	NA	NA	NA
2011	70 291	3.36	0.66	73 554	0.15	2.08	64 933	2.42	0.65	NA	NA	NA
2012	70 831	3.13	0.57	73 596	0.13	2.20	64 933	2.21	0.56	NA	NA	NA
2013	71 285	3.00	0.51	73 383	0.12	2.27	64 933	2.06	0.50	NA	NA	NA
2014	71 058	2.95	0.49	72 789	0.11	2.34	64 933	2.02	0.48	NA	NA	NA
2015	70 483	2.85	0.46	72 138	0.10	2.39	64 933	1.93	0.45	NA	NA	NA
Trend 1990-2015	-0.75%	-87.71%	-80.50%	-4.23%	-91.17%	352.66%	-0.21%	-90.01%	-80.80%	NA	NA	NA

Source: Environment Agency

Table 3-63, Table 3-64, Table 3-65 and Table 3-66 present the implied emission factors for each vehicle category.

Table 3-63 – Implied emission factors for passenger cars.

1 A Mobile Fuel Combustion			
Implied Emission Factor (IEF) of GHG by source category (g/GJ)			
Year	1 A 3 b i Road transport: Passenger cars		
	CO_2 (fossil)	*CH_4*	*N_2O*
1990	72070	18.960	1.981
1991	72073	17.194	2.144
1992	72163	14.541	2.417
1993	72173	12.331	2.652
1994	72190	10.249	2.794
1995	72179	9.022	2.914
1996	72089	8.055	2.918
1997	71908	7.248	2.836
1998	72120	6.331	2.665
1999	72119	5.539	2.497
2000	72095	4.876	2.355
2001	72253	4.286	2.214
2002	72310	3.777	2.075
2003	72308	3.342	1.949
2004	72372	2.928	1.849
2005	72449	2.555	1.779
2006	72588	2.229	1.734
2007	72630	1.965	1.705
2008	72778	1.742	1.673
2009	72737	1.553	1.658
2010	72753	1.411	1.651
2011	72706	1.316	1.639
2012	72779	1.191	1.622
2013	72937	1.084	1.626
2014	73029	1.040	1.630
2015	73000	0.975	1.634

Table 3-64 – Implied emission factors for light duty vehicles.

1 A Mobile Fuel Combustion			
Implied Emission Factor (IEF) of GHG by source category (g/GJ)			
Year	1 A 3 b ii Road transport: Light duty vehicles		
	CO_2 (fossil)	*CH_4*	*N_2O*
1990	72993	7.651	0.902
1991	73041	7.032	0.873
1992	73157	6.426	0.838
1993	73175	5.752	0.778
1994	73192	5.242	0.868
1995	73221	4.829	1.042
1996	73264	4.463	1.180
1997	73334	3.893	1.267
1998	73410	3.387	1.362
1999	73459	2.950	1.479
2000	73511	2.378	1.583
2001	73566	1.962	1.698
2002	73610	1.600	1.795
2003	73661	1.319	1.872
2004	73721	1.063	1.929
2005	73755	0.884	1.988
2006	73766	0.757	2.039
2007	73763	0.636	2.073
2008	73791	0.529	2.094
2009	73787	0.455	2.108
2010	73793	0.389	2.118
2011	73792	0.337	2.128
2012	73788	0.297	2.142
2013	73812	0.260	2.158
2014	73830	0.216	2.170
2015	73817	0.184	2.190

Table 3-65 – Implied emission factors for heavy duty vehicles.

1 A Mobile Fuel Combustion			
Implied Emission Factor (IEF) of GHG by source category (g/GJ)			
Year	1 A 3 b iii Road transport: Heavy duty vehicles		
	CO_2 (fossil)	*CH_4*	*N_2O*
1990	73871	0.812	0.583
1991	73885	0.790	0.572
1992	73911	0.804	0.576
1993	73870	0.853	0.591
1994	73847	0.886	0.607
1995	73842	0.904	0.615
1996	73851	0.877	0.612
1997	73851	0.820	0.604
1998	73857	0.769	0.601
1999	73855	0.715	0.595
2000	73827	0.652	0.577
2001	73825	0.606	0.544
2002	73825	0.573	0.506
2003	73844	0.541	0.467
2004	73870	0.503	0.442
2005	73882	0.439	0.521
2006	73876	0.369	0.661
2007	73862	0.298	0.944
2008	73874	0.234	1.291
2009	73867	0.198	1.516
2010	73867	0.161	1.721
2011	73859	0.134	1.912
2012	73852	0.116	2.052
2013	73862	0.101	2.160
2014	73874	0.087	2.244
2015	73858	0.074	2.303

Table 3-66 – Implied emission factors for mopeds and motorcycles.

1 A Mobile Fuel Combustion			
Implied Emission Factor (IEF) of GHG by source category (g/GJ)			
Year	1 A 3 b iv Road transport: Mopeds & motorcycles		
	CO_2 (fossil)	*CH_4*	*N_2O*
1990	71014	216.553	1.252
1991	71050	200.676	1.264
1992	71275	187.148	1.276
1993	71256	163.457	1.294
1994	71223	150.758	1.306
1995	71178	150.486	1.307
1996	71143	147.910	1.309
1997	71096	143.235	1.313
1998	71110	138.659	1.317
1999	71093	126.439	1.326
2000	71078	121.302	1.330
2001	71133	117.516	1.333
2002	71119	113.262	1.337
2003	71081	108.765	1.340
2004	71066	113.571	1.336
2005	71084	107.546	1.338
2006	71145	104.286	1.339
2007	71124	101.044	1.340
2008	71267	98.700	1.341
2009	71100	95.756	1.342
2010	71037	94.250	1.342
2011	71051	91.464	1.339
2012	70988	89.036	1.345
2013	71372	84.279	1.349
2014	71493	79.635	1.351
2015	71551	74.381	1.352

3.2.8.4 Railways (1A3c)

3.2.8.4.1 Source category description

Railways related GHG emissions are quite low in Luxembourg. The reason stems from the fact that Luxembourg's national railway company, *CFL (Chemins de Fer Luxembourgeois*), uses, almost exclusively, locomotives powered by electricity.

In 2015, railways fuel consumption was responsible for 0.08% of GHG emissions from fuel combustion activities (0.27% in 1990) and represented 0.07% of the total GHG emissions in CO_2e, excluding LULUCF (0.21% in 1990). Compared to 2014, emissions decreased by 32.38% to reach 7.03 Gg CO_2e in 2015. Compared to 1990, emissions decreased by 74.29%.

Activity data, GHG emissions and emission factors used to estimate emissions from *1A3c* are shown in Table 3-67. The V-shaped emission trend is mainly due to restructuring activities in the mid 2000s, where less diesel driven locomotive were used. Since 2007, the number of diesel driven locomotives has stabilised again between 70 and 80 units being operated per year.

GHG emissions from railways are not a key source.

Table 3-67 – Activity data, emissions and emission factors for IPCC sub-category 1A3c – Railways: 1990-2015

1A3c - Railways *Diesel Oil*												
Year	Activity (GJ)	Emissions (Gg)				Emission Factors (kg/TJ)						
		Total $CO_{2\,eq}$	CO_2	CH_4	N_2O	CO_2	type	CH_4	type	N_2O	type	source
1990	334 678	27.33	24.72	0.0012	0.0087	73 871	CS	3.68	D	25.88	D	AEV, 2006 IPCC GL
1991	334 678	27.34	24.73	0.0012	0.0087	73 885	CS	3.67	D	25.90	D	AEV, 2006 IPCC GL
1992	334 678	27.35	24.74	0.0012	0.0087	73 911	CS	3.66	D	25.93	D	AEV, 2006 IPCC GL
1993	334 678	27.34	24.72	0.0012	0.0087	73 870	CS	3.65	D	25.96	D	AEV, 2006 IPCC GL
1994	324 884	26.55	23.99	0.0012	0.0085	73 847	CS	3.63	D	26.07	D	AEV, 2006 IPCC GL
1995	263 059	21.50	19.42	0.0009	0.0069	73 842	CS	3.61	D	26.19	D	AEV, 2006 IPCC GL
1996	293 972	24.04	21.71	0.0011	0.0077	73 851	CS	3.59	D	26.30	D	AEV, 2006 IPCC GL
1997	288 989	23.64	21.34	0.0010	0.0076	73 851	CS	3.56	D	26.42	D	AEV, 2006 IPCC GL
1998	288 989	23.66	21.34	0.0010	0.0077	73 857	CS	3.54	D	26.54	D	AEV, 2006 IPCC GL
1999	288 989	23.67	21.34	0.0010	0.0077	73 855	CS	3.52	D	26.67	D	AEV, 2006 IPCC GL
2000	285 971	23.42	21.11	0.0010	0.0077	73 827	CS	3.49	D	26.81	D	AEV, 2006 IPCC GL
2001	308 159	25.25	22.75	0.0011	0.0083	73 825	CS	3.46	D	26.96	D	AEV, 2006 IPCC GL
2002	272 319	22.32	20.10	0.0009	0.0073	73 825	CS	3.36	D	26.97	D	AEV, 2006 IPCC GL
2003	237 417	19.45	17.53	0.0008	0.0064	73 844	CS	3.31	D	26.79	D	AEV, 2006 IPCC GL
2004	188 736	15.45	13.94	0.0006	0.0050	73 845	CS	3.25	D	26.61	D	AEV, 2006 IPCC GL
2005	119 838	9.79	8.85	0.0004	0.0031	73 859	CS	3.13	D	26.10	D	AEV, 2006 IPCC GL
2006	89 359	7.29	6.60	0.0003	0.0023	73 854	CS	3.01	D	25.57	D	AEV, 2006 IPCC GL
2007	127 161	10.07	9.13	0.0004	0.0031	71 797	CS	2.82	D	24.63	D	AEV, 2006 IPCC GL
2008	146 043	11.54	10.50	0.0004	0.0035	71 868	CS	2.62	D	23.68	D	AEV, 2006 IPCC GL
2009	140 637	11.06	10.10	0.0003	0.0032	71 807	CS	2.42	D	22.73	D	AEV, 2006 IPCC GL
2010	151 387	11.88	10.89	0.0003	0.0033	71 963	CS	2.22	D	21.76	D	AEV, 2006 IPCC GL
2011	151 568	11.83	10.88	0.0003	0.0032	71 778	CS	2.02	D	20.78	D	AEV, 2006 IPCC GL
2012	137 941	10.71	9.89	0.0003	0.0027	71 690	CS	1.92	D	19.91	D	AEV, 2006 IPCC GL
2013	119 277	9.19	8.52	0.0002	0.0022	71 405	CS	1.75	D	18.65	D	AEV, 2006 IPCC GL
2014	137 133	10.39	9.68	0.0002	0.0024	70 566	CS	1.58	D	17.37	D	AEV, 2006 IPCC GL
2015	94 152	7.03	6.56	0.0001	0.0016	69 640	CS	1.52	D	16.65	D	AEV, 2006 IPCC GL
Trend 1990-2015	-71.87%	-74.29%	-73.48%	-88.41%	-81.90%	-5.73%		-58.79%		-35.65%		

Source: Environment Agency

3.2.8.4.2 Methodological issues & time-series consistency

3.2.8.4.2.1 Activity data

Diesel oil consumption is obtained directly from the sole railway company (CFL). Activity data is consistent with the data reported by the national statistics institute in their energy balance (2000-2015). For the years 1990-1999, the energy balance (based on the IEA Questionnaire) does not report any consumption data for railways. Hence, the inventory fully relies on data as reported by the national railway company, which were available for the years 1993-1995 and 2001. The consumption for the years from 1996-2000 was interpolated based on the numbers of diesel driven locomotives running in the respective year. Similarly, for 1990-1992, the data was extrapolated based on the number of diesel driven locomotives.

3.2.8.4.2.2 Methodology

The 2006 IPCC Guidelines Tier 2 approach has been applied for CO_2 (use of country specific CO_2 emission factor). CH_4 and N_2O emissions were determined with the GEORG model (for details, please refer to section 3.2.7.8.2.2.).

3.2.8.4.2.3 Emission factors

The country specific CO_2 EF for diesel oil was used (Tier 2). CH_4 and N_2O emissions were determined with the GEORG model (Table 3-67).

3.2.8.5 Domestic Navigation (1A3d)

3.2.8.5.1 Source category description

As Luxembourg has no direct access to the sea, there are no maritime activities taking place. Similarly, Luxembourg has only one river where shipping activities are allowed, the Moselle, a border river with Germany. Shipping activities are mainly passenger (leisure and tourism) and freight activities.

In 2015, fuel consumption in navigation was responsible for 0.01% of GHG emissions from fuel combustion activities (0.01% in 1990) and represented 0.01% of the total GHG emissions in CO_2e, excluding LULUCF (0.01% in 1990). Compared to 2014, emissions have decreased by 12.76%. Compared to 1990, emissions have decreased by 22.48%.

Activity data and GHG emissions from *1A3d* are shown in Table 3-68.

Navigation related GHG emissions are not a key source.

Table 3-68 – Activity data and emissions for IPCC Sub-category 1A3d – Domestic Navigation: 1990-2015

1A3d - Navigation *Gas Oil, Diesel Oil, Motor Gasoline*					
Year	**Activity (GJ)**	**Emissions (Gg)**			
		Total $CO_{2\,eq}$	***CO_2***	***CH_4***	***N_2O***
1990	17 686	1.41	*1.30*	*0.0003*	*0.00034*
1991	19 272	1.53	*1.41*	*0.0004*	*0.00036*
1992	18 355	1.46	*1.35*	*0.0004*	*0.00034*
1993	19 240	1.53	*1.41*	*0.0004*	*0.00036*
1994	18 300	1.45	*1.34*	*0.0004*	*0.00035*
1995	15 753	1.26	*1.16*	*0.0003*	*0.00031*
1996	15 900	1.27	*1.17*	*0.0003*	*0.00031*
1997	16 295	1.30	*1.20*	*0.0003*	*0.00033*
1998	15 778	1.26	*1.16*	*0.0003*	*0.00032*
1999	17 416	1.40	*1.28*	*0.0003*	*0.00037*
2000	15 288	1.23	*1.13*	*0.0002*	*0.00034*
2001	17 136	1.38	*1.26*	*0.0003*	*0.00038*
2002	18 741	1.51	*1.38*	*0.0003*	*0.00042*
2003	19 601	1.58	*1.44*	*0.0003*	*0.00043*
2004	18 127	1.46	*1.34*	*0.0002*	*0.00040*
2005	19 205	1.55	*1.42*	*0.0002*	*0.00042*
2006	17 785	1.43	*1.31*	*0.0002*	*0.00037*
2007	18 305	1.44	*1.32*	*0.0002*	*0.00037*
2008	20 486	1.61	*1.48*	*0.0002*	*0.00041*
2009	17 077	1.33	*1.23*	*0.0002*	*0.00033*
2010	18 640	1.45	*1.35*	*0.0002*	*0.00035*
2011	17 577	1.37	*1.26*	*0.0001*	*0.00033*
2012	17 519	1.36	*1.26*	*0.0001*	*0.00032*
2013	15 331	1.18	*1.10*	*0.0001*	*0.00026*
2014	16 434	1.25	*1.17*	*0.0001*	*0.00027*
2015	14 552	1.09	*1.02*	*0.0001*	*0.00023*
Trend 1990-2015	*-17.72%*	*-22.48%*	*-21.46%*	*-67.57%*	*-31.99%*

Source: Environment Agency

3.2.8.5.2 Methodological issues & time-series consistency

3.2.8.5.2.1 Activity data

Fuel consumption data (gas oil) is obtained from the two national operators as no data is available from the official statistics. Indeed, no consumption is reported in the IEA Joint Questionnaire on oil products, probably due to the fact that the consumption is below 0.5 kt and that no digits are allowed in the questionnaire. The activity data are listed in Table 3-68.

Concerning the fuel consumption of leisure boats (yachts, jet-skis, etc), no data is available at this stage. However, only one (very) small marina exists on Luxembourg's side of the Moselle River: Schwebsange. This marina is equipped with a gasoline and diesel oil filling station. The amount of fuel sold at this station was obtained from the operator for the entire time-series.[101] It is assumed that the quantities sold at this station are being combusted entirely on Luxembourg's side of the river.

3.2.8.5.2.2 Methodology

The Tier 2 approach has been applied for CO_2 (use of country specific CO_2 emission factors), while CH_4 and N_2O emissions were determined with the GEORG model (for details, please refer to section 3.2.7.8.2.2).

Due to the particular geographical situation of the Moselle River, freight shipping activities, which are executed on barges, which do not refuel in Luxembourg's sole commercial port (Mertert), are not accounted for in Luxembourg's GHG inventory. These activities are exclusively international, *i.e.* destination is always abroad. For passenger shipping activities, the situation is different. There are two companies executing passenger shipping on the Moselle River. As communicated by these companies, about 80% of their journeys are to be considered domestic (from Luxembourg to Luxembourg), and the remaining 20% to be considered international (from Luxembourg to an international destination, or *vice versa*). Thus, the emissions from gasoil, reported under IPCC sub-category *1A3d - Domestic Navigation*, cover the 80% of domestic journeys. The emissions relating to the remaining 20% international journeys are reported under international bunkers – marine.

3.2.8.5.2.3 Emission factors

The country-specific CO_2 EFs were used. For CH_4 and N_2O, the emission factors were derived from the GEORG model (Table 3-69).

101 ARR 2009, §55

Table 3-69 – Emission factors for IPCC sub-category 1A3d – Domestic Navigation

1A3d - Navigation *Emission Factors for 2015 (kg/TJ)*									
Fuel	Fuel Type	CO_2		CH_4		N_2O		Source
		EF	type	EF	type	EF	type	
Diesel Oil	liquid	73 858	CS	2.49	CS	18.43	CS	AEV
Motor Gasoline	liquid	71 551	CS	34.93	CS	0.78	CS	AEV

Source: Environment Agency

3.2.8.6 Other Transportation (1A3e)

No activities have been identified for Luxembourg, hence notation key NA.

Whereas the IPCC 2006 Guidelines recommend to report emissions from vehicles and mobile machinery used within the agriculture, forestry, industry (including construction and maintenance), residential, and sectors, such as airport ground support equipment, agricultural tractors, chain saws, forklifts, snowmobiles in IPCC sub-category *1A3e – Other Transportation*, Luxembourg reports these emissions in the relevant IPCC sub-categories as follows:

- 1A2 Manufacturing Industries and Construction: sub-category 1A2g vii
- 1A4b ii Residential: Household and gardening
- 1A4c ii Agriculture: Tractors, Harvesters, *etc.*
- 1A5b Mobile: military equipment

Pipeline compressors, reported under *1A3e – Other Transportation*, do not exist in Luxembourg.

3.2.8.7 Uncertainties and time-series consistency

The uncertainties for activity data and emission factors used for IPCC category *1A3 – Transport* are presented in Table 3-70.

Table 3-70: uncertainties for activity data and emission factors used for IPCC category 1A3 – Transport.

IPCC category/Group	Gas	Activity data uncertainty (%)	Emission factor uncertainty (%)
1A3 - motor gasoline	CO2	2%	2%
1A3 - motor gasoline	CH4	2%	20%
1A3 - motor gasoline	N2O	2%	20%
1A3 - diesel oil	CO2	2%	2%
1A3 - diesel oil	CH4	2%	20%
1A3 - diesel oil	N2O	2%	20%
1A3 - LPG	CO2	2%	2%
1A3 - LPG	CH4	2%	40%

1A3 - LPG	N2O	2%	100%
1A3 - aviation gasoline	CO2	10%	5%
1A3 - aviation gasoline	CH4	10%	100%
1A3 - aviation gasoline	N2O	10%	150%

The time-series reported under *1A3 - Transportation*, are considered as being consistent. For more specific information on time-series consistency, please refer to the methodological issues as described in the respective sub-categories above.

3.2.8.8 Source-specific QA/QC and verification

Activity data obtained directly from the operators was cross checked with official statistics, if available, for plausibility.

Consistency and completeness checks have been performed using the tools embedded in CRF Reporter.

3.2.8.9 Category-specific recalculations including changes made in response to the review process

Table 3-71 presents the main revisions and recalculations done since submission 2016v1 relevant to IPCC sub-category *1A3 - Transport*. For the quantitative aspect of these recalculations, plese refer to Chapter 10.

Table 3-71 – Recalculations done since submission 2016v1

GHG source & sink category	Revisions 2016v1 ➔ 2017v1.2	Type of revision
1A3a	The CO_2 EF was corrected from 69300 to 70000 kg/TJ (IPCC 2006 Guidelines default value).	updated CO_2 EF
1A3b	Activity data were revised according to a new study[102].	updated AD
1A3b, 1A3d	Updated CO_2 EF for gasoline according to a recommendation from the ERT during the centralised UNFCCC review in September 2016.The ERT recommended that Luxembourg switches back to the previous approach where a country-specific CO_2 emission factor for gasoline is determined according to the quantities of gasoline imported from the different countries and the respective emission factors used by these countries. This approach is used in this submission for the entire time-series, in all sub-categories to which gasoline is allocated (1A2gvii, 1A3b, 1A3d, 1A4b).	updated CO_2 EF

[102] Komobile, FVT: Aktualisierung der Zeitreihen zum Kraftstoff-export und der Emissionen von klimarelevanten Gasen und Luftschadstoffen des Verkehrssektors in Luxemburg von 1990 - 2015, Endbericht, 2017, Graz, Luxemburg

3.2.8.10 Category-specific planned improvements including those in response to the review process

Taking into account the potential contribution of identified improvements in the total GHG emissions and the corresponding resources needed to make these improvements effective, developments presented in Table 3-72 will be explored.

Table 3-72 – Planned improvements for IPCC Sub-category 1A3 – Transport

GHG source & sink category	Planned improvement
1A3 - Transportation	No planned improvements

3.2.9 Other Sectors (1.A4)

3.2.9.1 Source category description

This section describes GHG emissions resulting from fuel combustion activities in the category *1A4 - Other sectors* and covers combustion activities from stationary combustion and mobile combustion in sub-categories:

- *1A4a – Commercial/Institutional*
- *1A4b – Residential*
- *1A4c - Agriculture/Forestry/Fishing*

In 2015, category *1A4 - Other sectors* was responsible for 17.75% of GHG emissions from fuel combustion activities (this share was 13.23% in 1990) and represented around 14.58% of the total GHG emissions excluding LULUCF (10.65% in 1990).

Compared to 2014, emissions increased by 13.29%, to attain the level of 1568 Gg CO_2e. Compared to 1990 emissions increased by 183.98%, mainly due to the steady increase in population and economic activity over the last two decades.

1A4 – Other Sectors is a key category regarding CO_2 emissions. It has been a key category for gaseous and liquid fuels without interruption since 1990, see Table 3-6 in Section 3.2.

Table 3-73 – GHG emission trends for category *1A4 – Other Sectors*: 1990-2015

Year	1A4 - Other Sectors: GHG emissions by source & sink category excluding CO_2 emissions from biomass (Gg)											
	1A4a - Commercial/Institutional				1A4b - Residential				1A4c - Agriculture/Forestry/Fisheries			
	Total $CO_{2\,eq}$	CO_2 (excl. biomass)	CH_4 (incl. biomass)	N_2O (incl. biomass)	Total $CO_{2\,eq}$	CO_2 (excl. biomass)	CH_4 (incl. biomass)	N_2O (incl. biomass)	Total $CO_{2\,eq}$	CO_2 (excl. biomass)	CH_4 (incl. biomass)	N_2O (incl. biomass)
1990	640.16	*637.05*	*0.08*	*0.004*	678.85	*667.89*	*0.35*	*0.007*	36.65	*33.91*	*0.003*	*0.009*
1991	770.15	*766.35*	*0.09*	*0.005*	813.59	*801.58*	*0.38*	*0.008*	37.49	*34.81*	*0.003*	*0.009*
1992	710.60	*707.16*	*0.09*	*0.004*	747.72	*736.55*	*0.36*	*0.007*	35.76	*33.24*	*0.003*	*0.008*
1993	702.46	*699.10*	*0.08*	*0.004*	741.78	*730.54*	*0.36*	*0.007*	33.61	*31.15*	*0.003*	*0.008*
1994	676.83	*673.60*	*0.08*	*0.004*	706.14	*695.77*	*0.33*	*0.007*	36.00	*33.42*	*0.003*	*0.008*
1995	682.30	*679.09*	*0.08*	*0.004*	716.08	*705.46*	*0.34*	*0.007*	34.30	*31.69*	*0.003*	*0.008*
1996	761.54	*757.99*	*0.09*	*0.004*	785.96	*775.64*	*0.33*	*0.007*	35.93	*33.27*	*0.003*	*0.009*
1997	738.29	*734.79*	*0.09*	*0.004*	761.62	*751.43*	*0.32*	*0.007*	37.38	*34.69*	*0.003*	*0.009*
1998	772.36	*768.72*	*0.09*	*0.005*	792.10	*782.03*	*0.31*	*0.007*	38.13	*35.32*	*0.003*	*0.009*
1999	692.13	*688.93*	*0.08*	*0.004*	711.22	*701.65*	*0.30*	*0.007*	55.45	*52.52*	*0.005*	*0.009*
2000	548.23	*546.11*	*0.06*	*0.002*	1 077.55	*1 066.48*	*0.34*	*0.009*	27.57	*24.72*	*0.002*	*0.009*
2001	498.40	*496.23*	*0.06*	*0.002*	1 169.82	*1 157.99*	*0.36*	*0.010*	24.37	*21.84*	*0.002*	*0.008*
2002	500.43	*498.20*	*0.06*	*0.002*	1 113.50	*1 102.52*	*0.33*	*0.009*	25.97	*23.30*	*0.002*	*0.009*
2003	497.13	*495.08*	*0.06*	*0.002*	1 156.69	*1 145.52*	*0.34*	*0.009*	26.25	*23.62*	*0.002*	*0.009*
2004	462.90	*461.01*	*0.05*	*0.002*	1 237.43	*1 225.58*	*0.36*	*0.010*	27.64	*25.00*	*0.002*	*0.009*
2005	418.25	*416.54*	*0.05*	*0.002*	1 211.99	*1 200.54*	*0.35*	*0.009*	26.99	*24.55*	*0.002*	*0.008*
2006	395.34	*393.93*	*0.04*	*0.001*	1 199.93	*1 188.46*	*0.35*	*0.009*	27.48	*25.11*	*0.002*	*0.008*
2007	348.55	*347.27*	*0.04*	*0.001*	1 160.15	*1 149.53*	*0.32*	*0.009*	26.95	*24.71*	*0.002*	*0.007*
2008	376.96	*375.66*	*0.04*	*0.001*	1 193.15	*1 181.95*	*0.34*	*0.009*	29.17	*26.83*	*0.002*	*0.008*
2009	380.45	*379.12*	*0.04*	*0.001*	1 179.67	*1 167.92*	*0.36*	*0.009*	29.25	*27.01*	*0.003*	*0.007*
2010	498.51	*496.64*	*0.05*	*0.002*	1 158.09	*1 146.46*	*0.36*	*0.009*	29.32	*27.20*	*0.002*	*0.007*
2011	332.51	*331.23*	*0.04*	*0.001*	1 061.32	*1 051.57*	*0.30*	*0.008*	27.85	*25.94*	*0.002*	*0.006*
2012	439.55	*437.90*	*0.05*	*0.002*	1 079.92	*1 068.70*	*0.35*	*0.009*	27.99	*26.16*	*0.002*	*0.006*
2013	464.17	*462.27*	*0.05*	*0.002*	1 072.61	*1 060.82*	*0.37*	*0.009*	23.95	*22.45*	*0.002*	*0.005*
2014	388.76	*387.05*	*0.05*	*0.002*	970.61	*958.65*	*0.38*	*0.008*	24.58	*23.12*	*0.002*	*0.005*
2015	475.67	*473.61*	*0.06*	*0.002*	1 067.06	*1 054.91*	*0.38*	*0.009*	25.20	*23.80*	*0.002*	*0.005*
Trend 1990-2015	*-25.70%*	*-25.66%*	*-28.29%*	*-42.59%*	*57.19%*	*57.95%*	*7.93%*	*23.24%*	*-31.25%*	*-29.83%*	*-47.80%*	*-48.91%*
Trend 2014-2015	*22.36%*	*22.36%*	*14.56%*	*35.29%*	*9.94%*	*10.04%*	*0.93%*	*4.13%*	*2.50%*	*2.93%*	*-1.70%*	*-4.35%*

Source: Environment Agency

Notes:

CO_2 emissions do not include CO2 emissions from biomass which are reported under Memo Items.

CH_4 emissions are converted in CO_2e by multiplying the emissions by 25, *i.e.* the global warming potential (*GWP*) value for methane based on the effects of GHG over a 100-year time horizon.

N_2O emissions are converted in CO_2e by multiplying the emissions by 298, *i.e.* the global warming potential (*GWP*) value for nitrous oxide based on the effects of GHG over a 100-year time horizon.

3.2.9.2 Commercial/Institutional (1A.4.a)

3.2.9.2.1 Source category description

In 2015, fuel combustion activities from the commercial and institutional sector were responsible for 5.38% of GHG emissions from fuel combustion activities (this share was also 6.25% in 1990). With regard to total GHG emissions excluding LULUCF, *1A4a – Commercial/Institutional* covered 4.42% in 2015 and 5.03% in 1990. Compared to 2014, GHG emissions have increased by 22.36% to reach the level of 475.67 Gg CO_2e in 2015. This sharp decrease cannot be explained for the moment, although the decreased consumption in this category has been confirmed by the national statistical institute providing the national energy balance. It could well be that the number will be revised in the next submission. Compared to 1990, emissions in this sub-category decreased by 164.49%.

3.2.9.2.2 Methodological issues & time-series consistency

3.2.9.2.2.1 Activity data

Under *1A4a – Commercial/Institutional*, emissions from non-industrial commercial and institutional combustion plants (<50 MW) are accounted, thus covering numerous small combustion units, mainly for the heating purpose of buildings. No specific bottom-up data is available, so that emission estimates solely rely on top-down data from the national energy balance.

However, for the period 1990-1999, fuel consumption data is only reported under the so-called "*domestic sector*" by the national energy balance, covering consumption data for commercial and institutional as well as for residential combustion units. Consequently, data was distributed arbitrarily, *i.e.* 50% is reported under *1A4a - Commercial/Institutional* and 50% under *1A4b - Residential*. From 2000 onwards, the consumption data reported by the national energy balance is properly split between the two categories *1A4a* and *1A4b*.

The total activity rate of category *1A4a* has been relatively constant in recent years (Table 3-74), with sharp decreases in 2007, 2011 and 2014, probably due to relatively mild winters.

Table 3-74 – Activity data for category *1A4a – Commercial/Institutional*

1A4a - Commercial/Institutional *Activity Data by fuel type (GJ)*						
Year	Activity Total	Solid	Liquid *Gas Oil, LPG*	Gaseous *Natural Gas*	Biomass	Other
1990	9 296 234	NO	6 359 553	2 936 681	NO	NO
1991	11 122 561	NO	7 822 330	3 300 231	NO	NO
1992	10 323 786	NO	6 985 232	3 338 553	NO	NO
1993	10 259 446	NO	6 708 868	3 550 579	NO	NO
1994	9 898 224	NO	6 406 937	3 491 287	NO	NO
1995	10 042 374	NO	6 223 973	3 818 401	NO	NO
1996	11 278 089	NO	6 794 806	4 483 283	NO	NO
1997	10 906 999	NO	6 718 170	4 188 829	NO	NO
1998	11 463 249	NO	6 954 434	4 506 815	2 000	NO
1999	10 387 398	NO	5 942 758	4 441 640	3 000	NO
2000	8 915 370	NO	2 673 823	6 220 885	20 662	NO
2001	7 837 822	NO	3 312 877	4 491 584	33 361	NO
2002	7 957 180	NO	3 009 270	4 902 833	45 078	NO
2003	7 974 408	NO	2 693 297	5 243 119	37 993	NO
2004	7 357 752	NO	2 685 214	4 642 785	29 753	NO
2005	6 615 090	NO	2 495 701	4 091 000	28 389	NO
2006	6 505 067	NO	1 498 922	4 977 905	28 240	NO
2007	5 730 623	NO	1 383 477	4 319 537	27 609	NO
2008	6 337 908	NO	1 084 008	5 220 321	33 579	NO
2009	6 383 542	NO	1 065 826	5 275 683	42 033	NO
2010	8 125 816	NO	2 378 209	5 710 750	36 856	NO
2011	5 345 946	NO	1 889 732	3 416 530	39 684	NO
2012	7 180 854	NO	2 117 970	5 018 938	43 946	NO
2013	7 502 352	NO	2 555 405	4 887 692	59 255	NO
2014	6 261 853	NO	2 235 325	3 957 828	68 699	NO
2015	7 449 224	NO	3 324 466	4 069 499	55 259	NO
Trend 1990-2015	-19.87%	NA	-47.72%	38.57%	NA	NA
Trend 2014-2015	18.96%	NA	48.72%	2.82%	-19.56%	NA

Source: Environment Agency

3.2.9.2.2.2 Methodology

The 2006 IPCC Guidelines Tier 2 approach has been applied for CO_2 for all fuels except for biomass (only biogas is used) for which a Tier 1 approach was used, while the Tier 1 approach was used for CH_4 and N_2O.

3.2.9.2.2.3 Emission factors

Default CH_4 and N_2O emission factors have been applied for all fuels. For biomass (only biogas is used) the IPCC default CO_2 EF was applied. For gas oil, diesel oil, LPG and natural gas, country specific CO_2 emission factors were used (Table 3-75).

Table 3-75 – Emission factors for category *1A4a – Commercial/Institutional*

1A4a - Commercial/Institutional *Emission Factors for 2015 (kg/TJ)*								
Fuel	Fuel Type	CO_2		CH_4		N_2O		Source
		EF	type	EF	type	EF	type	
LPG	liquid	64 933	CS	5.00	D	0.10	D	AEV 2006 IPCC GL
Gas Oil	liquid	73 858	CS	10.00	D	0.60	D	AEV 2006 IPCC GL
Natural Gas	gaseous	56 760	CS	5.00	D	0.10	D	AEV 2006 IPCC GL
Biogas	biomass	54 600	D	5.00	D	0.10	D	2006 IPCC GL

Source: Environment Agency

Table 3-76 gives an overview of the evolution of the implied emission factors per fuel type. The slight fluctuations for the CH_4 and NO_2 IEFs for liquid fuels are due to fluctuations in the fuel mix (gasoil and LPG).

Table 3-76 – Implied emission factors for IPCC sub-category 1A4a – Commercial/Institutional

1A4a - Commercial/Institutional *Implied Emission Factors (kg/TJ)*									
Year	Biomass			Liquid			Gaseous		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
1990	NO	NO	NO	73 503	9.79	0.58	57 755	5.00	0.10
1991	NO	NO	NO	73 608	9.84	0.58	57 743	5.00	0.10
1992	NO	NO	NO	73 589	9.82	0.58	57 848	5.00	0.10
1993	NO	NO	NO	73 565	9.83	0.58	57 894	5.00	0.10
1994	NO	NO	NO	73 563	9.84	0.58	57 940	5.00	0.10
1995	NO	NO	NO	73 570	9.85	0.58	57 929	5.00	0.10
1996	NO	NO	NO	73 584	9.85	0.59	57 546	5.00	0.10
1997	NO	NO	NO	73 706	9.92	0.59	57 205	5.00	0.10
1998	54 600	5.00	0.10	73 686	9.90	0.59	56 863	5.00	0.10
1999	54 600	5.00	0.10	73 683	9.90	0.59	56 522	5.00	0.10
2000	64 673	56.77	0.78	73 442	9.78	0.58	56 221	5.00	0.10
2001	70 298	85.68	1.17	73 515	9.83	0.58	56 258	5.00	0.10
2002	82 520	148.49	2.00	73 673	9.91	0.59	56 396	5.00	0.10
2003	69 387	81.00	1.10	73 765	9.96	0.60	56 533	5.00	0.10
2004	61 886	42.45	0.60	73 699	9.90	0.59	56 671	5.00	0.10
2005	60 977	37.78	0.53	73 615	9.85	0.59	56 910	5.00	0.10
2006	57 239	18.56	0.28	73 486	9.78	0.58	57 008	5.00	0.10
2007	57 558	20.20	0.30	73 695	9.91	0.59	56 793	5.00	0.10
2008	61 151	38.67	0.55	73 659	9.88	0.59	56 665	5.00	0.10
2009	65 362	60.31	0.83	73 286	9.67	0.57	57 056	5.00	0.10
2010	63 650	51.51	0.71	72 649	9.32	0.53	56 712	5.00	0.10
2011	58 593	25.52	0.37	72 250	9.10	0.51	56 988	5.00	0.10
2012	65 585	61.46	0.85	72 172	9.06	0.51	56 793	5.00	0.10
2013	71 433	91.51	1.24	72 487	9.23	0.52	56 680	5.00	0.10
2014	74 973	109.71	1.48	72 662	9.32	0.53	56 756	5.00	0.10
2015	64 961	58.25	0.80	72 981	9.51	0.55	56 760	5.00	0.10

Source: Environment Agency

3.2.9.3 Residential (1A4b)

3.2.9.3.1 Source category description

In 2015, fuel combustion activities in the residential sector were responsible for 12.08% of GHG emissions from fuel combustion activities (6.63% in 1990). With regard to total GHG emissions excluding LULUCF emissions from *1A4b – Residential* reached 9.92% in 2015 and 5.33% in 1990. Compared to 2014, GHG emissions increased by 9.94%, probably due to a colder winter.

3.2.9.3.2 Methodological issues & time-series consistency

3.2.9.3.2.1 Activity data

Under *1A4b – Residential*, the following activities have been classified:

- *Non-industrial residential combustion plants* < *50 MW*: This source category covers numerous smaller combustion units, mainly for heating purposes. No specific bottom-up data is available, so that emission estimates solely rely on top-down data provided by the national statistics institute. The consumption of coke, hard coal (other bituminous coal), lignite briquettes (brown coal briquettes), patent fuels, wood, gas oil, LPG and natural gas was obtained from the national statistics institute.
  However, for 1990-1999, the consumptions of gasoil and natural gas are reported under the so-called "*domestic sector*" by the national statistics institute, covering consumptions both from commercial and institutional as well as from residential combustion. Consequently, data was distributed arbitrarily, *i.e.* 50% was allocated to *1A4a - Commercial/Institutional* and 50% to *1A4b - Residential*. From 2000-2015, the consumptions reported by the national statistics institute are properly split between the two sub-categories *1A4a* and *1A4b*.
- *Household and gardening*: Gasoline consumption was allocated to this sub-category. An average of 0.57 motorised gardening tools per household was assumed[103].

Activity data for both stationary and mobile sources, as described above, are listed in Table 3-77.

[103] Komobile, FVT: Aktualisierung der Zeitreihen zum Kraftstoff-export und der Emissionen von klimarelevanten Gasen und Luftschadstoffen des Verkehrssektors in Luxemburg von 1990 - 2015, Endbericht, 2017, Graz, Luxemburg

Table 3-77 – Activity data for category *1A4b – Residential*

1A4b - Residential *Fuel consumption by fuel type (GJ)*						
Year	Activity Total (excl. biomass)	Solid *Coke Oven Coke, Brown Coal Briquettes, Other Bituminous Coal*	Liquid *Gas Oil, LPG, Gasoline*	Gaseous *Natural Gas*	Biomass *Wood and similar wood wastes*	Other
1990	9 630 362	*268 741*	*6 424 941*	*2 936 681*	*645 000*	*NO*
1991	12 146 417	*313 244*	*7 887 942*	*3 300 231*	*645 000*	*NO*
1992	11 287 935	*253 192*	*7 051 190*	*3 338 553*	*645 000*	*NO*
1993	11 242 074	*271 499*	*6 774 996*	*3 550 579*	*645 000*	*NO*
1994	10 788 362	*179 141*	*6 472 934*	*3 491 287*	*645 000*	*NO*
1995	10 967 208	*214 226*	*6 289 581*	*3 818 401*	*645 000*	*NO*
1996	12 121 949	*133 647*	*6 860 019*	*4 483 283*	*645 000*	*NO*
1997	11 740 381	*123 577*	*6 782 975*	*4 188 829*	*645 000*	*NO*
1998	12 260 387	*89 753*	*7 018 819*	*4 506 815*	*645 000*	*NO*
1999	11 177 514	*83 642*	*6 007 233*	*4 441 640*	*645 000*	*NO*
2000	16 638 357	*63 651*	*9 381 808*	*6 560 642*	*632 256*	*NO*
2001	18 091 223	*51 351*	*10 115 994*	*7 241 170*	*682 708*	*NO*
2002	17 288 926	*40 632*	*9 297 132*	*7 320 304*	*630 859*	*NO*
2003	17 994 471	*29 511*	*9 464 317*	*7 856 398*	*644 245*	*NO*
2004	19 260 236	*27 390*	*10 030 033*	*8 516 240*	*686 572*	*NO*
2005	18 869 333	*30 074*	*9 645 313*	*8 536 993*	*656 953*	*NO*
2006	18 551 659	*25 786*	*9 967 333*	*7 899 632*	*658 908*	*NO*
2007	17 966 466	*21 523*	*9 495 761*	*7 861 031*	*588 151*	*NO*
2008	18 602 634	*19 861*	*9 529 612*	*8 407 485*	*645 676*	*NO*
2009	18 403 342	*21 702*	*9 438 351*	*8 226 956*	*716 333*	*NO*
2010	18 498 320	*25 322*	*8 128 170*	*9 602 707*	*742 120*	*NO*
2011	16 877 398	*22 774*	*7 247 769*	*9 027 820*	*579 036*	*NO*
2012	17 114 397	*18 751*	*8 055 210*	*8 315 615*	*724 820*	*NO*
2013	17 202 379	*26 584*	*7 580 239*	*8 797 046*	*798 509*	*NO*
2014	15 816 312	*20 182*	*6 467 333*	*8 443 674*	*885 123*	*NO*
2015	17 300 167	*25 780*	*7 062 105*	*9 356 143*	*856 138*	*NO*
Trend 1990-2015	*79.64%*	*-90.41%*	*9.92%*	*218.60%*	*32.73%*	*NA*
Trend 2014-2015	*9.38%*	*27.74%*	*9.20%*	*10.81%*	*-3.27%*	*NA*

Source: Environment Agency

3.2.9.3.2.2 Methodology

For stationary sources, the 2006 IPCC Guidelines Tier 2 approach has been applied for CO_2, while the Tier 1 approach was used for CH_4 and N_2O.

For mobile sources, the 2006 IPCC Guidelines Tier 2 approach has been applied for CO_2, while the method used for CH_4 and N_2O is based on the GEORG model which conforms to the requirements of the IPCC 2006 GL Tier 3 methodology. The methodology is described in section 3.2.7.8.2.2.

3.2.9.3.2.3 Emission factors

CH_4 and N_2O emission factors have been derived from the GEORG model, while country specific CO_2 emission factors were used for the main fuels: see Table 3-78.

Table 3-78 – Emission factors for IPCC sub-category 1A4b – Residential

1A4b - Residential								
Emission Factors for 2015 (kg/TJ)								
Fuel	Fuel Type	CO_2		CH_4		N_2O		Source
		EF	type	EF	type	EF	type	
Coke Oven Coke	solid	107 000	D	300.00	D	1.50	D	2006 IPCC GL
Brown Coal Briquettes	solid	97 500	D	300.00	D	1.50	D	2006 IPCC GL
Other Bituminous Coal	solid	94 600	D	300.00	D	1.50	D	2006 IPCC GL
Patent Fuels	solid	97 500	D	300.00	D	1.50	D	2006 IPCC GL
LPG	liquid	64 933	CS	5.00	D	0.10	D	AEV 2006 IPCC GL
Gas Oil	liquid	73 858	CS	10.00	D	0.60	D	AEV 2006 IPCC GL
Gasoline	liquid	71 551	CS	26.46	CS	1.12	CS	AEV
Natural Gas	gaseous	56 760	CS	5.00	D	0.10	D	AEV 2006 IPCC GL
Wood and similar wood wastes	biomass	112 000	D	300.00	D	4.00	D	2006 IPCC GL

Source: Environment Agency

Table 3-79 gives an overview of the evolution of the implied emission factors per fuel type.

Table 3-79 – Implied emission factors for IPCC sub-category 1A4b – Residential

1A4b - Residential									
Implied Emission Factors (kg/TJ)									
Year	Solid			Liquid			Gaseous		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
1990	97 464	300	1.50	73 478	10.26	0.58	57 755	5.00	0.10
1991	97 593	300	1.50	73 587	10.22	0.59	57 743	5.00	0.10
1992	97 515	300	1.50	73 567	10.25	0.59	57 848	5.00	0.10
1993	98 441	300	1.50	73 543	10.28	0.59	57 894	5.00	0.10
1994	97 530	300	1.50	73 539	10.30	0.59	57 940	5.00	0.10
1995	101 287	300	1.50	73 545	10.30	0.59	57 929	5.00	0.10
1996	97 350	300	1.50	73 561	10.25	0.59	57 546	5.00	0.10
1997	97 367	300	1.50	73 681	10.31	0.60	57 205	5.00	0.10
1998	97 365	300	1.50	73 662	10.26	0.60	56 863	5.00	0.10
1999	97 303	300	1.50	73 656	10.30	0.60	56 522	5.00	0.10
2000	97 500	300	1.50	73 699	10.19	0.60	56 221	5.00	0.10
2001	97 500	300	1.50	73 706	10.17	0.60	56 258	5.00	0.10
2002	97 500	300	1.50	73 757	10.21	0.60	56 396	5.00	0.10
2003	97 500	300	1.50	73 803	10.22	0.60	56 533	5.00	0.10
2004	97 500	300	1.50	73 806	10.18	0.60	56 671	5.00	0.10
2005	97 500	300	1.50	73 795	10.16	0.60	56 910	5.00	0.10
2006	97 500	300	1.50	73 801	10.15	0.60	57 008	5.00	0.10
2007	97 500	300	1.50	73 820	10.16	0.60	56 793	5.00	0.10
2008	97 500	300	1.50	73 833	10.14	0.60	56 665	5.00	0.10
2009	97 500	300	1.50	73 785	10.10	0.60	57 056	5.00	0.10
2010	97 500	300	1.50	73 743	10.08	0.60	56 712	5.00	0.10
2011	97 500	300	1.50	73 798	10.12	0.60	56 988	5.00	0.10
2012	97 500	300	1.50	73 816	10.11	0.60	56 793	5.00	0.10
2013	97 500	300	1.50	73 825	10.11	0.60	56 680	5.00	0.10
2014	97 500	300	1.50	73 825	10.13	0.60	56 756	5.00	0.10
2015	97 500	300	1.50	73 822	10.12	0.60	56 760	5.00	0.10

Source: Environment Agency

3.2.9.4 Agriculture/Forestry/Fishing (1A4c)

3.2.9.4.1 Source category description

Luxembourg reports emissions for the following sub-categories:

- *Stationary (1A4c.i)*
- *Off-road vehicles and other machinery (1A4c.ii)*

Sub-category *1A4c.iii Fishing* (mobile combustion) does not exist in Luxembourg.

In 2015, fuel combustion activities in agriculture and forestry were responsible for 0.29% of GHG emissions from fuel combustion activities (0.39% in 1990). With regard to total GHG emissions excluding LULUCF, emissions from *1A4c – Agriculture/Forestry/ Fishing* reached 0.23% in 2015 and 0.29% in 1990. Compared to 2014, GHG emissions increased by 2.50%.

Emissions of *1A4c - Agriculture/Forestry/Fishing* are shown in Table 3-73 at the beginning of this section.

3.2.9.4.2 Methodological issues & time-series consistency

3.2.9.4.2.1 Activity data

Under *1A4c – Agriculture/Forestry/Fishing*, the following activities have been classified:

- *Non-industrial combustion plants in agriculture, forestry and aquaculture*: The fuel consumption data of this activity is derived from the national energy balance. However, only the consumption of gas oil is reported for the entire time-series. Natural gas is only reported from 2000 onwards, but its consumption is very small (below 1400 GJ per year). Other fuels might be included elsewhere by the national energy balance.
- *Mobile machinery used in forestry and agriculture*: Diesel oil and gasoline consumption was attributed to mobile machinery used in forestry and agriculture (i.e. tractors, harvesters, chainsaws, etc.) based on stock data and economic indicators[104].

Activity data from both stationary and mobile sources, as described above, are listed in Table 3-80.

[104] Komobile, FVT: Aktualisierung der Zeitreihen zum Kraftstoff-export und der Emissionen von klimarelevanten Gasen und Luftschadstoffen des Verkehrssektors in Luxemburg von 1990 - 2015, Endbericht, 2017, Graz, Luxemburg

Table 3-80 – Activity data and implied emission factors for category *1A4c – Agriculture/Forestry/Fishing*

1A4c - Agriculture/Forestry/Fishing *Activity Data and Implied Emission Factors (kg/TJ)*										
Year	Activity (GJ)	Liquid			Gaseous			Biomass		
		CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
1990	459 277	73 839	6.52	19.48	NO	NO	NO	NO	NO	NO
1991	471 334	73 853	6.71	18.54	NO	NO	NO	NO	NO	NO
1992	449 947	73 880	6.83	18.24	NO	NO	NO	NO	NO	NO
1993	421 890	73 837	6.70	19.03	NO	NO	NO	NO	NO	NO
1994	452 782	73 816	6.74	18.54	NO	NO	NO	NO	NO	NO
1995	429 408	73 809	6.51	19.78	NO	NO	NO	NO	NO	NO
1996	450 720	73 820	6.58	19.25	NO	NO	NO	NO	NO	NO
1997	469 877	73 820	6.68	18.68	NO	NO	NO	NO	NO	NO
1998	479 436	73 828	6.56	19.13	NO	NO	NO	54 600	5.00	0.10
1999	714 319	73 835	7.64	13.20	NO	NO	NO	54 600	5.00	0.10
2000	343 614	73 786	4.79	28.20	56 221	5.00	0.10	54 600	5.00	0.10
2001	317 699	73 779	4.88	28.34	56 258	5.00	0.10	54 600	5.00	0.10
2002	343 529	73 782	4.68	27.96	56 396	5.00	0.10	54 600	5.00	0.10
2003	376 688	73 802	4.53	27.17	56 533	5.00	0.10	54 600	5.00	0.10
2004	426 659	73 829	4.26	25.77	56 671	5.00	0.10	54 600	5.00	0.10
2005	459 721	73 841	4.07	24.14	56 910	5.00	0.10	54 600	5.00	0.10
2006	495 680	73 837	3.88	22.93	57 008	5.00	0.10	54 600	5.00	0.10
2007	513 430	73 823	3.77	21.90	56 793	5.00	0.10	54 600	5.00	0.10
2008	578 983	73 839	3.58	21.01	56 665	5.00	0.10	54 600	5.00	0.10
2009	630 095	73 831	3.47	20.00	57 056	5.00	0.10	54 600	5.00	0.10
2010	576 538	73 831	3.34	18.78	56 712	5.00	0.10	54 600	5.00	0.10
2011	538 977	73 821	3.28	17.70	NO	NO	NO	54 600	5.00	0.10
2012	543 446	73 813	3.18	16.73	NO	NO	NO	54 600	5.00	0.10
2013	471 421	73 823	3.28	16.01	NO	NO	NO	54 600	5.00	0.10
2014	433 089	73 838	3.17	15.22	56 756	5.00	0.10	54 600	5.00	0.10
2015	440 596	73 824	3.02	14.14	56 760	5.00	0.10	54 600	5.00	0.10

Source: Environment Agency

3.2.9.4.2.2 Methodological issues

For stationary sources, the 2006 IPCC Guidelines Tier 2 approach has been applied for CO_2, while the Tier 1 approach was used for CH_4 and N_2O.

For mobile sources, the 2006 IPCC Guidelines Tier 2 approach has been applied for CO_2, while the method used for CH_4 and N_2O is based on the GEORG model which conforms to the requirements of the IPCC 2006 GL Tier 3 methodology. The methodology is described in section 3.2.7.8.2.2.

3.2.9.4.2.3 Emission factors

Country-specific CO_2 emission factors have been applied for natural gas, gas oil and diesel oil. For stationary sources, default 2006 IPCC emission factors were used for CH_4, N_2O and CO_2 from biomass. For mobile sources, emission factors for CH_4 and N_2O were derived from the GEORG model (Table 3-81).

Table 3-81 – Emission factors for category *1A4c – Agriculture/Forestry/Fishing*

1A4c - Agriculture/Forestry/Fishing Emission Factors for 2015 (kg/TJ)								
Fuel	Fuel Type	CO_2		CH_4		N_2O		Source
		EF	type	EF	type	EF	type	
Gas Oil	liquid	73 858	CS	10.00	D	0.60	D	AEV 2006 IPCC GL
Diesel Oil	liquid	73 858	CS	1.89	CS	14.34	CS	AEV
Biogas	biomass	54 600	D	5.00	D	0.10	D	2006 IPCC GL
Natural Gas	gaseous	56 760	CS	5.00	D	0.10	D	AEV 2006 IPCC GL

Source: Environment Agency

An overview of the evolution of the implied emission factors per fuel type is given in Table 3-80.

3.2.9.5 Uncertainties and time-series consistency

The uncertainties for activity data and emission factors used for IPCC category *1A4 – Other Sectors* are presented in Table 3-82**Error! Reference source not found.**.

Table 3-82: uncertainties for activity data and emission factors used for IPCC category 1A4 – Other Sectors.

IPCC category/Group	Gas	Activity data uncertainty (%)	Emission factor uncertainty (%)
1A4 - Gaseous Fuels	CO2	2%	1%
1A4 - Gaseous Fuels	CH4	2%	50%
1A4 - Gaseous Fuels	N2O	2%	50%
1A4 - Liquid Fuels	CO2	2%	1%
1A4 - Liquid Fuels	CH4	2%	50%
1A4 - Liquid Fuels	N2O	2%	50%
1A4 - Biomass	CH4	7%	50%
1A4 - Biomass	N2O	7%	60%
1A4 - Solid Fuels	CO2	1%	3%
1A4 - Solid Fuels	CH4	1%	50%
1A4 - Solid Fuels	N2O	1%	50%

The time series reported under *1A4 - Other Sectors*, are considered to be consistent, to the best of data availability. Further investigations will be needed, in collaboration with the national statistics institute, to see whether, for the years 1990-1999, the arbitrary 50/50 split between 1A4a and 1A4b could be replaced by a more accurate split.

3.2.9.6 Source-specific QA/QC and verification

Standard QA/QC procedures (including consistency and completeness checks) were executed according to the QA/QC policy.

3.2.9.7 Category-specific recalculations including changes made in response to the review process

Table 3-83 presents the main revisions and recalculations relevant to category *1A4 – Other Sectors* since the last submission to the UNFCCC.

As explained in section 3.2.7.11, major revisions in the energy balance have been done for natural gas allocated to the categories 1.A.2 – Manufacturing industries and construction and 1.A.4 – Other sectors to decrease the previously relatively large difference (around 5%) between the reference approach and the sectoral approach for natural gas allocated to 1.A.2.f – Non-metallic minerals. This resulted in an important recalculation of natural gas activity data in the sectors 1.A.2 – Manufacturing industries and construction and 1.A.4 – Other sectors for the years 2000-2015.

Table 3-83 – Recalculations done since submission 2016v1

GHG source & sink category	Revisions 2016v ➔ 2017v1.2	Type of revision
1A4a	AD for gasoil, natural gas and biomass was revised due to a revised energy balance by the national statistics institute.	AD
1A4b, 1A4c	AD for mobile machinery were updated according to a new study[105].	AD
1A4b, 1A4c	Updated CO_2 EF for gasoline according to a recommendation from the ERT during the centralised UNFCCC review in September 2016.The ERT recommended that Luxembourg switches back to the previous approach where a country-specific CO_2 emission factor for gasoline is determined according to the quantities of gasoline imported from the different countries and the respective emission factors used by these countries. This approach is used in this submission for the entire time-series, in all sub-categories to which gasoline is allocated (1A2gvii, 1A3b, 1A3d, 1A4b).	CO_2 EF for gasoline

3.2.9.8 Category-specific planned improvements including those in response to the review process

Considering the potential contribution of identified improvements in the total GHG emissions and the corresponding resources needed to make these improvements effective, developments presented in Table 3-84 will be explored.

Table 3-84 – Planned improvements for category *1A4 – Other Sectors*

GHG source & sink category	Planned improvement

[105] Komobile, FVT: Aktualisierung der Zeitreihen zum Kraftstoff-export und der Emissionen von klimarelevanten Gasen und Luftschadstoffen des Verkehrssektors in Luxemburg von 1990 - 2015, Endbericht, 2017, Graz, Luxemburg

1A4a – Commercial/Institutional, 1A4b – Residential	collecting information helping to refine the fuel consumption split between the commercial/institutional sectors, on the one hand, and the residential sector, on the other hand.

3.2.10 Other (1.A.5.)

3.2.10.1 Source category description

This section describes GHG emissions resulting from fuel combustion activities in category *1A5 – Other*. It covers combustion activities from stationary combustion and mobile combustion in sub-categories:

- *1A5a – Stationary*: Building and Plant Site Fuel Powered Machinery
- *1A5b – Mobile*: Military Vehicles

In 2015, category 1A5 - Other was responsible for 0.001% of GHG emissions from fuel combustion activities (this share was 0.03% in 1990) and represented around 0.001% of the total GHG emissions excluding LULUCF (0.02% in 1990).

Compared to 2014, emissions decreased by 0.18%, to attain the level of 0.13 Gg CO2e. Compared to 1990 emissions decreased by 95.96%.

1A5 - Other related CO_2 emissions from liquid fuels have been identified as a key category in 1999.

Table 3-85 summarizes GHG emissions for category *1A5 – Other*.

Table 3-85 – GHG emission trends in CO_2e for category 1A5 – Other: 1990-2015

Year	1A5a - Stationary				1A5b - Mobile				1A5 - Other			
	Total $CO_{2\,eq}$	*CO_2*	*CH_4*	*N_2O*	Total $CO_{2\,eq}$	*CO_2*	*CH_4*	*N_2O*	Total $CO_{2\,eq}$	*CO_2*	*CH_4*	*N_2O*
1990	2.98	*2.98*	*0.0002*	*0.0000*	0.14	*0.13*	*0.000006*	*0.000*	3.12	*3.10*	*0.000*	*0.000*
1991	2.98	*2.98*	*0.0002*	*0.0000*	0.14	*0.13*	*0.000006*	*0.000*	3.12	*3.10*	*0.000*	*0.000*
1992	26.66	*26.52*	*0.0034*	*0.0002*	0.14	*0.13*	*0.000006*	*0.000*	26.80	*26.65*	*0.003*	*0.000*
1993	23.50	*23.37*	*0.0030*	*0.0002*	0.14	*0.13*	*0.000006*	*0.000*	23.64	*23.50*	*0.003*	*0.000*
1994	21.91	*21.79*	*0.0028*	*0.0002*	0.14	*0.13*	*0.000006*	*0.000*	22.05	*21.92*	*0.003*	*0.000*
1995	10.64	*10.59*	*0.0013*	*0.0001*	0.14	*0.12*	*0.000005*	*0.000*	10.78	*10.71*	*0.001*	*0.000*
1996	18.39	*18.30*	*0.0023*	*0.0001*	0.14	*0.12*	*0.000005*	*0.000*	18.53	*18.42*	*0.002*	*0.000*
1997	22.89	*22.78*	*0.0027*	*0.0001*	0.14	*0.12*	*0.000005*	*0.000*	23.03	*22.91*	*0.003*	*0.000*
1998	33.97	*33.80*	*0.0041*	*0.0002*	0.14	*0.12*	*0.000005*	*0.000*	34.10	*33.92*	*0.004*	*0.000*
1999	62.93	*62.61*	*0.0078*	*0.0004*	0.14	*0.12*	*0.000005*	*0.000*	63.07	*62.73*	*0.008*	*0.000*
2000	12.08	*12.05*	*0.0009*	*0.0000*	0.14	*0.12*	*0.000005*	*0.0000*	12.21	*12.17*	*0.001*	*0.000*
2001	24.10	*24.04*	*0.0019*	*0.0000*	0.14	*0.12*	*0.000005*	*0.0000*	24.24	*24.16*	*0.002*	*0.000*
2002	13.40	*13.37*	*0.0010*	*0.0000*	0.13	*0.12*	*0.000004*	*0.0000*	13.54	*13.49*	*0.001*	*0.000*
2003	3.14	*3.13*	*0.0002*	*0.0000*	0.13	*0.12*	*0.000004*	*0.0000*	3.27	*3.25*	*0.000*	*0.000*
2004	NO	*NO*	*NO*	*NO*	0.13	*0.12*	*0.000004*	*0.0000*	0.13	*0.12*	*0.0000*	*0.0000*
2005	NO	*NO*	*NO*	*NO*	0.13	*0.12*	*0.000003*	*0.0000*	0.13	*0.12*	*0.0000*	*0.0000*
2006	NO	*NO*	*NO*	*NO*	0.13	*0.12*	*0.000003*	*0.0000*	0.13	*0.12*	*0.0000*	*0.0000*
2007	NO	*NO*	*NO*	*NO*	0.13	*0.12*	*0.000003*	*0.0000*	0.13	*0.12*	*0.0000*	*0.0000*
2008	NO	*NO*	*NO*	*NO*	0.13	*0.12*	*0.000002*	*0.0000*	0.13	*0.12*	*0.0000*	*0.0000*
2009	NO	*NO*	*NO*	*NO*	0.13	*0.12*	*0.000002*	*0.0000*	0.13	*0.12*	*0.0000*	*0.0000*
2010	NO	*NO*	*NO*	*NO*	0.13	*0.12*	*0.000002*	*0.0000*	0.13	*0.12*	*0.0000*	*0.0000*
2011	NO	*NO*	*NO*	*NO*	0.13	*0.12*	*0.000002*	*0.0000*	0.13	*0.12*	*0.0000*	*0.0000*
2012	NO	*NO*	*NO*	*NO*	0.13	*0.12*	*0.000002*	*0.0000*	0.13	*0.12*	*0.0000*	*0.0000*
2013	NO	*NO*	*NO*	*NO*	0.13	*0.12*	*0.000002*	*0.0000*	0.13	*0.12*	*0.0000*	*0.0000*
2014	NO	*NO*	*NO*	*NO*	0.13	*0.12*	*0.000002*	*0.0000*	0.13	*0.12*	*0.0000*	*0.0000*
2015	NO	*NO*	*NO*	*NO*	0.13	*0.12*	*0.000002*	*0.0000*	0.13	*0.12*	*0.0000*	*0.0000*
Trend 1990-2015	*NA*	*NA*	*NA*	*NA*	*-10.23%*	*-4.42%*	*-65.58%*	*-63.92%*	*-95.96%*	*-96.10%*	*-99.14%*	*-67.22%*

Table group heading: 1A5 - Other — *GHG emissions by source & sink category (Gg)*

Source: Environment Agency

Notes:

CO_2 emissions do not include CO_2 emissions from biomass which are reported under Memo Items.

CH_4 emissions are converted in CO_2e by multiplying the emissions by 25, *i.e.* the global warming potential (*GWP*) value for methane based on the effects of GHG over a 100-year time horizon.

N_2O emissions are converted in CO_2e by multiplying the emissions by 298, *i.e.* the global warming potential (*GWP*) value for nitrous oxide based on the effects of GHG over a 100-year time horizon.

3.2.10.2 Stationary (1A5a)

3.2.10.2.1 Source category description

In 2015, no emissions from fuel combustion activities from *1A5a - Stationary* were reported (notation key NO). In 1990, this category was responsible for 0.03% of GHG emissions from fuel combustion activities. With regard to total GHG emissions excluding LULUCF, the share was 0.02% in 1990.

3.2.10.2.2 Methodological issues & time-series consistency:

3.2.10.2.2.1 Activity data

Fuel consumption data (gas oil, LPG) is obtained from the national statistics institute and was attributed to this sub-category based on expert judgement. Activity data is listed in Table 3-86.

3.2.10.2.2.2 Methodology

The 2006 IPCC Guidelines Tier 2 approach has been applied to CO_2, whereas the Tier 1 approach was applied to CH_4 and N_2O.

Table 3-86 – Activity data and implied emission factors for category *1A5 – Other*

1A5 - Other

Activity Data and Implied Emission Factors (kg/TJ)

Year	1A5a - Stationary - Liquid (LPG, Gas Oil)				1A5b - Mobile - Liquid (Diesel Oil)			
	Activity (GJ)	CO_2	CH_4	N_2O	Activity (GJ)	CO_2	CH_4	N_2O
1990	45 728	65 068	5.00	0.10	1 715	73 871	3.40	26.53
1991	45 728	65 099	5.00	0.10	1 712	73 885	3.39	26.57
1992	364 308	72 792	9.37	0.54	1 710	73 911	3.37	26.62
1993	321 934	72 600	9.29	0.53	1 707	73 870	3.35	26.66
1994	300 654	72 491	9.24	0.52	1 699	73 847	3.29	27.00
1995	148 456	71 308	8.58	0.46	1 686	73 842	3.20	27.57
1996	252 683	72 413	9.19	0.52	1 675	73 851	3.11	28.10
1997	321 685	70 824	8.30	0.43	1 664	73 851	3.03	28.63
1998	473 779	71 342	8.59	0.46	1 653	73 857	2.94	29.17
1999	869 847	71 982	8.91	0.49	1 643	73 855	2.86	29.68
2000	185 497	64 943	5.00	0.10	1 636	73 827	2.81	30.02
2001	370 223	64 942	5.00	0.10	1 631	73 825	2.77	30.25
2002	205 847	64 957	5.00	0.10	1 626	73 825	2.63	29.78
2003	48 158	64 976	5.00	0.10	1 620	73 844	2.40	28.67
2004	NO	NO	NO	NO	1 619	73 870	2.19	26.84
2005	NO	NO	NO	NO	1 621	73 882	1.99	24.40
2006	NO	NO	NO	NO	1 624	73 876	1.79	21.92
2007	NO	NO	NO	NO	1 627	73 862	1.62	19.33
2008	NO	NO	NO	NO	1 631	73 874	1.51	16.96
2009	NO	NO	NO	NO	1 635	73 867	1.44	14.99
2010	NO	NO	NO	NO	1 637	73 867	1.38	13.53
2011	NO	NO	NO	NO	1 638	73 859	1.35	12.43
2012	NO	NO	NO	NO	1 639	73 852	1.32	11.56
2013	NO	NO	NO	NO	1 640	73 862	1.28	10.93
2014	NO	NO	NO	NO	1 640	73 874	1.25	10.44
2015	NO	NO	NO	NO	1 640	73 858	1.23	10.01

Source: Environment Agency

3.2.10.2.2.3 Emission factors

Country specific CO_2 emission factors were applied to gas oil and LPG, whereas for CH_4 and N_2O, default 2006 IPCC emission factors were used (Table 3-87).

Table 3-87 – Emission factors for category *1A5 – Other*

1A5 - Other *Emission Factors for 2015 (kg/TJ)*								
Fuel	Fuel Type	CO_2		CH_4		N_2O		Source
		EF	type	EF	type	EF	type	
LPG	liquid	64 933	CS	5.00	D	0.10	D	AEV 2006 IPCC GL
Gas Oil	liquid	73 858	CS	10.00	D	0.60	D	AEV 2006 IPCC GL
Diesel Oil	liquid	73 858	CS	4.15	D	28.60	D	AEV 2006 IPCC GL

Source: Environment Agency

An overview of the evolution of the implied emission factors per fuel type is given in Table 3-86 .

3.2.10.3 Mobile (1A5b)

3.2.10.3.1 Source category description

In 2015, fuel combustion activities in 1A5b – Mobile were responsible for 0.001% of GHG emissions from fuel combustion activities (0.001% in 1990). With regard to total GHG emissions excluding LULUCF emissions from 1A5b – Mobile reached 0.001% in 2015 and 0.001% in 1990. Compared to 2014, GHG emissions decreased by 0.18%.

3.2.10.3.2 Methodological issues & time-series consistency

3.2.10.3.2.1 Activity data

Fuel consumption data (diesel oil) from military vehicles was attributed to this sub-category based on expert judgement[106]. Activity data is listed in Table 3-86.

3.2.10.3.2.2 Methodology

The 2006 IPCC Guidelines Tier 2 approach has been applied for CO_2, while the method used for CH_4 and N_2O is based on the GEORG model which conforms to the requirements of the IPCC 2006 GL Tier 3 methodology. The methodology is described in section 3.2.7.8.2.2.

3.2.10.3.2.3 Emission factors

Country-specific CO_2 emission factors have been applied to diesel oil, whereas for CH_4 and N_2O, emission factors were derived from the GEORG model (Table 3-87).

[106] Komobile, FVT: Aktualisierung der Zeitreihen zum Kraftstoff-export und der Emissionen von klimarelevanten Gasen und Luftschadstoffen des Verkehrssektors in Luxemburg von 1990 - 2015, Endbericht, 2017, Graz, Luxemburg

3.2.10.4 Uncertainties and time-series consistency

The uncertainties for activity data and emission factors used for IPCC category *1A5 – Other* are presented in Table 3-88.

Table 3-88: uncertainties for activity data and emission factors used for IPCC category 1A5 – Other.

IPCC category/Group	Gas	Activity data uncertainty (%)	Emission factor uncertainty (%)
1A5 - Gaseous Fuels	CO2	2%	1%
1A5 - Gaseous Fuels	CH4	2%	50%
1A5 - Gaseous Fuels	N2O	2%	50%

IPCC category/Group	Gas	Base year emissions or removals	Year x emissions or removals	Activity dat uncertainty
		Gg CO2 equivalent	Gg CO2 equivalent	%
		input data	input data	input dat Note A
1A Stationary Combustion - Gaseous Fuels	CO2	1035.80	1828.10	
1A Stationary Combustion - Gaseous Fuels	CH4	1.04	2.15	
1A Stationary Combustion - Gaseous Fuels	N2O	0.53	0.96	
1A Stationary Combustion - Liquid Fuels	CO2	1274.51	1022.89	
1A Stationary Combustion - Liquid Fuels	CH4	3.48	2.72	
1A Stationary Combustion - Liquid Fuels	N2O	14.85	12.41	
1A Stationary Combustion - Other Fuels	CO2	33.29	129.35	
1A Stationary Combustion - Other Fuels	CH4	0.25	1.08	
1A Stationary Combustion - Other Fuels	N2O	0.40	1.72	
1A Stationary Combustion - Biomass	CH4	5.50	8.10	
1A Stationary Combustion - Biomass	N2O	1.81	3.55	
1A Stationary Combustion - Solid Fuels	CO2	5317.44	165.41	
1A Stationary Combustion - Solid Fuels	CH4	5.40	0.62	
1A Stationary Combustion - Solid Fuels	N2O	5.94	0.78	

The time series reported under *1A5 - Other* are considered to be consistent.

3.2.10.5 Source-specific QA/QC and verification

Standard QA/QC procedures (including consistency and completeness checks) were executed according to the QA/QC policy.

3.2.10.6 Category-specific recalculations including changes made in response to the review process

Table 3-90 presents the main revisions and recalculations relevant to category *1A5 – Other* since the last submission to the UNFCCC.

Table 3-89 – Recalculations done since submission 2016v1

GHG source & sink category	Revisions 2016v1 ➔ 2017v1.2	Type of revision
1A5b	Activity data for 1A5b has been revides based on a new study[107]. Until submission 2016v1 the activity data reported in this sub-category corresponded to fuel consumptions allocated to "Other – including military, and non-attributable consumption" in the national energy balance. However, activity data was only available from 1992 to 1999. In submission 2017v1.2, activity data reported under 1A5b corresponds only to fuel consumption estimated for military vehicles for the entire time-series.	Updated AD
1A5b	The method used for estimating CH_4 and N_2O emissions from 1A5b is based on the GEORG model which conforms to the requirements of the IPCC 2006 GL Tier 3 methodology.	CH_4 and N_2O methodology and EFs

3.2.10.7 Category-specific planned improvements including those in response to the review process

No further improvements are planned.

[107] Komobile, FVT: Aktualisierung der Zeitreihen zum Kraftstoff-export und der Emissionen von klimarelevanten Gasen und Luftschadstoffen des Verkehrssektors in Luxemburg von 1990 - 2015, Endbericht, 2017, Graz, Luxemburg

3.3 *Fugitive Emissions from Fuels (1.B)*

3.3.1 Solid Fuels (1.B.1)

This category does not exist in Luxembourg.

3.3.2 Oil and natural gas and other emissions from energy production (1.B.2)

3.3.2.1 Source category description

In Luxembourg, fugitive emissions only occur from natural gas transmission and storage and distribution (sub-categories *1B2b3 – Transmission and Storage* and *1B2b4 – Distribution*). Other fugitive emissions – because they are closely linked to production, processing or exploration – are not occurring in Luxembourg.

Fugitive emissions from the distribution of refined oil products (category 1B2a5) are reported with notation key *NA* in the CRF tables, as only NMVOC emissions occur.

In 2015, fugitive emissions from category *1B2 – Oil and natural gas and other emissions from energy production* were responsible for 0.39% of GHG emissions from the energy sector (0.19% in 1990) and represented 0.32% of the total GHG emissions excluding LULUCF (0.15% in 1990). Compared to 2014, fugitive GHG emissions decreased by 10.07% due to a lower natural gas consumption. Table 3-90 summarizes GHG emissions for category *1B2 – Oil and natural gas and other emissions from energy production*.

Fugitive emissions from *1B2 – Oil and natural gas and other emissions from energy production* are not a key category.

Table 3-90 – GHG emission trends in CO_2e for category *1B2 – Oil and natural gas and other emissions from energy production*: 1990-2015

1B2 - Oil and Natural Gas

CO_2e emissions (Gg)

Year	1B2a - Oil				1B2b - Natural Gas				1B2c - Venting & Flaring				1B2d - Other			
	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O
1990	NA	NA	NA	NO	19.39	0.03	19.36	NA, NO	NO	NO	NO	NO	NA	NA	NA	NA
1991	NA	NA	NA	NO	20.11	0.03	20.09	NA, NO	NO	NO	NO	NO	NA	NA	NA	NA
1992	NA	NA	NA	NO	20.99	0.03	20.96	NA, NO	NO	NO	NO	NO	NA	NA	NA	NA
1993	NA	NA	NA	NO	21.79	0.03	21.76	NA, NO	NO	NO	NO	NO	NA	NA	NA	NA
1994	NA	NA	NA	NO	21.94	0.03	21.91	NA, NO	NO	NO	NO	NO	NA	NA	NA	NA
1995	NA	NA	NA	NO	25.01	0.03	24.98	NA, NO	NO	NO	NO	NO	NA	NA	NA	NA
1996	NA	NA	NA	NO	27.36	0.04	27.33	NA, NO	NO	NO	NO	NO	NA	NA	NA	NA
1997	NA	NA	NA	NO	27.98	0.04	27.95	NA, NO	NO	NO	NO	NO	NA	NA	NA	NA
1998	NA	NA	NA	NO	28.20	0.04	28.17	NA, NO	NO	NO	NO	NO	NA	NA	NA	NA
1999	NA	NA	NA	NO	29.20	0.04	29.16	NA, NO	NO	NO	NO	NO	NA	NA	NA	NA
2000	NA	NA	NA	NO	29.98	0.04	29.94	NA, NO	NO	NO	NO	NO	NA	NA	NA	NA
2001	NA	NA	NA	NO	33.32	0.04	33.27	NA, NO	NO	NO	NO	NO	NA	NA	NA	NA
2002	NA	NA	NA	NO	47.72	0.06	47.66	NA, NO	NO	NO	NO	NO	NA	NA	NA	NA
2003	NA	NA	NA	NO	48.36	0.06	48.30	NA, NO	NO	NO	NO	NO	NA	NA	NA	NA
2004	NA	NA	NA	NO	53.67	0.07	53.60	NA, NO	NO	NO	NO	NO	NA	NA	NA	NA
2005	NA	NA	NA	NO	52.87	0.07	52.80	NA, NO	NO	NO	NO	NO	NA	NA	NA	NA
2006	NA	NA	NA	NO	55.48	0.07	55.41	NA, NO	NO	NO	NO	NO	NA	NA	NA	NA
2007	NA	NA	NA	NO	51.91	0.07	51.84	NA, NO	NO	NO	NO	NO	NA	NA	NA	NA
2008	NA	NA	NA	NO	49.64	0.07	49.57	NA, NO	NO	NO	NO	NO	NA	NA	NA	NA
2009	NA	NA	NA	NO	50.18	0.07	50.11	NA, NO	NO	NO	NO	NO	NA	NA	NA	NA
2010	NA	NA	NA	NO	53.96	0.07	53.89	NA, NO	NO	NO	NO	NO	NA	NA	NA	NA
2011	NA	NA	NA	NO	46.78	0.06	46.72	NA, NO	NO	NO	NO	NO	NA	NA	NA	NA
2012	NA	NA	NA	NO	47.85	0.06	47.79	NA, NO	NO	NO	NO	NO	NA	NA	NA	NA
2013	NA	NA	NA	NO	40.74	0.05	40.69	NA, NO	NO	NO	NO	NO	NA	NA	NA	NA
2014	NA	NA	NA	NO	38.47	0.05	38.42	NA, NO	NO	NO	NO	NO	NA	NA	NA	NA
2015	NA	NA	NA	NO	34.60	0.05	34.55	NA, NO	NO	NO	NO	NO	NA	NA	NA	NA
Trend 1990-2015	NA	NA	NA	NA	78.46%	78.46%	78.46%	NA	NA	NA	NA	NA	NA	NA	NA	NA
Trend 2014-2015	NA	NA	NA	NA	-10.07%	-10.07%	-10.07%	NA	NA	NA	NA	NA	NA	NA	NA	NA

Source: Environment Agency

Notes: CH_4 emissions are converted in CO_2e by multiplying the emissions by 25, *i.e.* the global warming potential (*GWP*) value for methane based on the effects of GHG over a 100-year time horizon.

3.3.2.2 Methodological issues

3.3.2.2.1 Activity data

Activity data on national natural gas consumption are obtained from the national statistics institute and are listed in Table 3-91.

Table 3-91 – Activity data for category *1B2 – Oil and natural gas and other emissions from energy production*: 1990-2015

Natural Gas Consumption (GJ)									
1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
17'933'317	18'646'148	19'434'013	20'184'361	20'334'431	23'237'685	25'491'947	26'121'115	26'375'108	27'358'063
2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
28'107'906	31'246'200	44'666'100	45'214'200	50'068'800	49'248'165	51'513'517	48'083'522	45'771'030	46'576'577
2010	**2011**	**2012**	**2013**	**2014**	**2015**				
50'098'694	43'218'993	44'005'398	37'258'454	35'301'256	32'193'861				

Source: STATEC: Statistical Yearbook, table A4200 (natural gas) and converted to the NCV basis. As extracted on 23rd March 2017.

3.3.2.2.2 Methodology

The 2006 IPCC Guidelines Tier 1 approach has been applied.

3.3.2.2.3 Emission factors

2006 IPCC Guidelines default emission factors have been applied:

- Natural Gas Transmission - CO_2: .... $8.8*10^{-7}$ Gg/10^6 m^3
- Natural Gas Distribution - CO_2: .... $5.1*10^{-5}$ Gg/10^6 m^3
- Natural Gas Transmission - CH_4: .... $4.8*10^{-4}$ Gg/10^6 m^3
- Natural Gas Distribution - CH_4: .... $1.1*10^{-3}$ Gg/10^6 m^3

Emission factors from the 2006 IPCC Guidelines were selected as these best reflect the modern and regularly serviced transmission and distribution natural gas networks in Luxembourg. The distribution network is continuously expanded as the population grows (approx. 2.5% per year), whereas the length of the transmission network has remained constant over the last years.

3.3.2.3 Uncertainties and time-series consistency

The uncertainties for activity data and emission factors used for IPCC category *1B2 - Oil and natural gas and other emissions from energy production* are presented in Table 3-92.

Table 3-92: uncertainties for activity data and emission factors used for IPCC category 1B2 - Oil and natural gas and other emissions from energy production.

IPCC category/Group	Gas	Activity data uncertainty (%)	Emission factor uncertainty (%)
1B2b – Natural Gas	CO2	2%	100%
1B2b – Natural Gas	CH4	2%	100%

The time series reported under *1B2 - Oil and natural gas and other emissions from energy production* are considered to be consistent. Fluctuations in the time series occur due to maintenance stops of large industrial plants such as the 350 MWe CHP gas turbine (Twinerg), the closure of iron and steel facilities (2012- ArcelorMittal Schifflange) or more heat demand due to colder winters. Although the population grows rapidly in Luxembourg, this does not necessarily induce a growth in natural gas demand as buildings get more and more energy efficient through better insulation.

3.3.2.4 Source-specific QA/QC and verification

Standard QA/QC procedures were followed.

Consistency and completeness checks have been performed using the tools embedded in CRF Reporter.

3.3.2.5 Category-specific recalculations including changes made in response to the review process

Table 3-93 presents the main revisions and recalculations relevant to category *1B2 – Oil and natural gas and other emissions from energy production* since the last submission to the UNFCCC. For the quantitative aspect of these recalculations, plese refer to Chapter 10.

Table 3-93 – Recalculations done since submission 2016v1

GHG source & sink category	Revisions 2016v1 ➔ 2017v1.2	Type of revision
1B2	No revisions were made.	

3.3.2.6 Category-specific planned improvements including those in response to the review process

Taking into account the potential contribution of identified improvements in the total GHG emissions and the corresponding resources needed to make these improvements effective, developments presented in Table 3-94 will be explored.

Table 3-94 – Planned improvements for category *1B2 – Oil and natural gas and other emissions from energy production*

GHG source & sink category	Planned improvement
1B2a5 - Distribution of refined oil products	Assess whether these emissions occur and, if appropriate, estimate and report fugitive emissions from the infrastructure supporting the transport, distribution, storage and sale of refined fuel oils.

4 Industrial Processes (CRF sector 2)

4.1 Sector Overview

Chapter 4 includes information on and description of methodologies used for estimating GHG emissions as well as references to activity data and emission factors reported under CRF Sector 2 – *Industrial Processes* for the period 1990 to 2015.

Emissions from this sector comprise emissions from the following categories: mineral products (2A), metal production (2C) and consumption of halocarbons (2F), SF_6 and N_2O (2G). For more details on categories where emissions are not occurring and categories that are not estimated or included elsewhere, see Tables 4-2 and 4-3.

Only process related emissions are considered in this sector. Emissions due to fuel combustion in manufacturing industries are allocated to IPCC Sub-category *1A2 – Fuel Combustion Activities – Manufacturing Industries and Construction* (see Chapter 3).

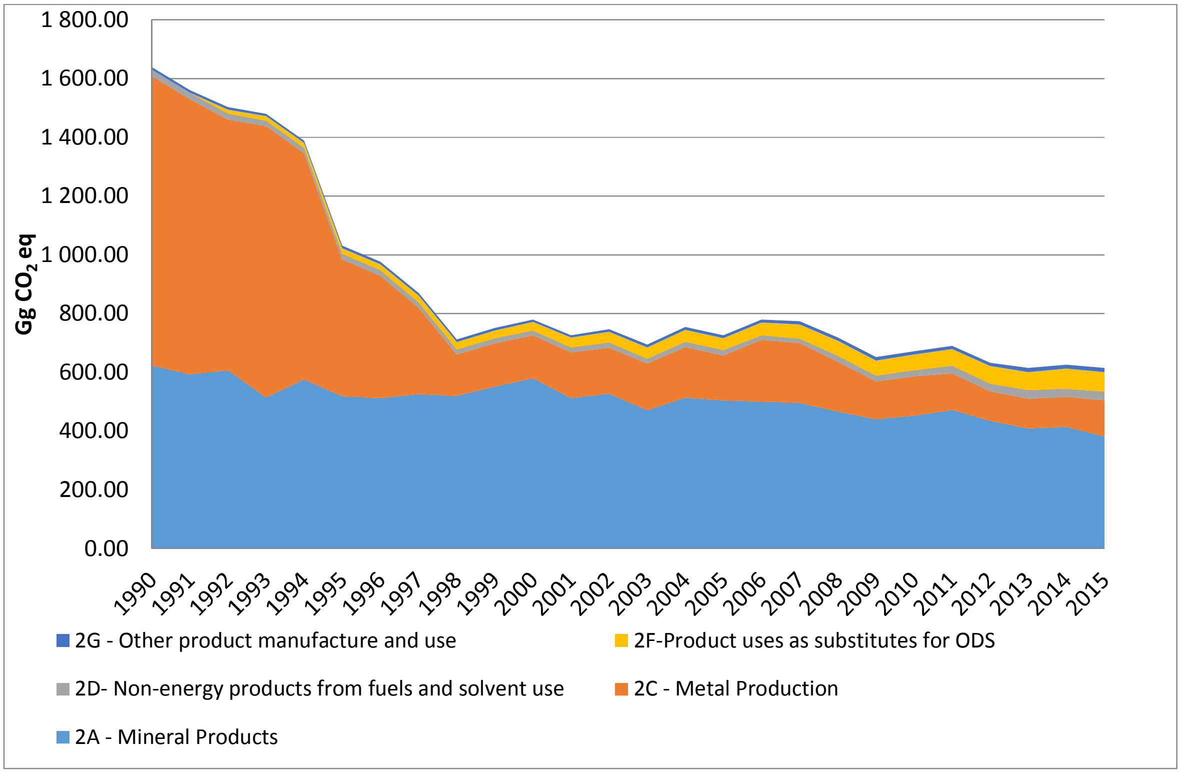
4.1.1 Emission Trends

This section briefly describes the emission trends from 1990 to 2015 for each of the IPCC categories under CRF Sector 2 for which GHG emissions are reported – *i.e.* categories *2A – Mineral Products*, *2C – Metal Production, 2D-Non-energy products from fuels and solvent use*, *2F-Product uses as substitutes for ODS, and 2G- Other product manufacture and use.*

Industrial process emissions include emissions from industrial installations and from consumption of halocarbons and SF_6 (the fluorinated gases (HFCs and SF_6) or F-gases), while PFCs are not in use in Luxembourg. The most important emitting activities are clinker, flat glass and iron and steel productions. With regard to F-gases, increasing emissions are mainly due to a growing use of air conditioning.

As shown in Table 4-1 and Figure 4-1, emissions of GHG due to industrial processes have decreased by about 61.69% between 1990 and 2015 (-66.44% for carbon dioxide but +23743.02% for F-gases). It is for IPCC Category *2C – Metal Production* that CO_2 emissions have decreased the most over the period: -87.53%. For IPCC Category 2A – Mineral Products the decline is limited to -36.72% for CO_2 emissions.

Figure 4-1 – GHG emission trends for CRF Sector 2 – Industrial Processes: 1990-2015



The trend observed for the iron and steel production units is, of course, linked to the dramatic change that occurred in the 1990s with regard to the production process: move from blast furnaces to electrical arc furnaces. This technological change has already been developed in previous chapters (see, *e.g.*, Chapter 2) and will not be detailed once again here.

The striking increase of F-gas emissions is the consequence of supposedly growing use in the country, but also of the hypothesis made for their estimation: see Section 4.7.

Figure 4-2 and Figure 4-3 provide a quick overview on industrial processes related emission trends between 1990 and 2015. More explanations are presented in the subsequent sections detailing each of the sector source sub-categories.

Table 4-1 – GHG emission trends in CO_2e for CRF Sector 2 – Industrial Processes: 1990-2015

Year	2A - Mineral Products				2C - Metal Production				2D- Non-energy products from fuels and solvent use			
	2 - Industrial Processes — *GHG emissions by source & sink category (Gg CO_2 eq)*											
	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O
1990	623.45	623.45	NO	NO	984.91	984.91	NO	NO	21.83	21.83	NO	NO
1991	592.76	592.76	NO	NO	937.74	937.74	NO	NO	21.32	21.32	NO	NO
1992	607.15	607.15	NO	NO	853.29	853.29	NO	NO	20.25	20.25	NO	NO
1993	515.03	515.03	NO	NO	923.19	923.19	NO	NO	19.20	19.20	NO	NO
1994	575.35	575.35	NO	NO	770.83	770.83	NO	NO	18.45	18.45	NO	NO
1995	519.11	519.11	NO	NO	465.38	465.38	NO	NO	19.94	19.94	NO	NO
1996	512.12	512.12	NO	NO	416.60	416.60	NO	NO	19.64	19.64	NO	NO
1997	525.97	525.97	NO	NO	294.10	294.10	NO	NO	18.73	18.73	NO	NO
1998	520.30	520.30	NO	NO	140.69	140.69	NO	NO	17.65	17.65	NO	NO
1999	551.34	551.34	NO	NO	147.70	147.70	NO	NO	16.97	16.97	NO	NO
2000	579.74	579.74	NO	NO	146.05	146.05	NO	NO	16.15	16.15	NO	NO
2001	513.12	513.12	NO	NO	154.76	154.76	NO	NO	16.46	16.46	NO	NO
2002	528.32	528.32	NO	NO	155.40	155.40	NO	NO	17.97	17.97	NO	NO
2003	471.66	471.66	NO	NO	158.94	158.94	NO	NO	15.59	15.59	NO	NO
2004	513.37	513.37	NO	NO	172.45	172.45	NO	NO	18.22	18.22	NO	NO
2005	503.80	503.80	NO	NO	152.92	152.92	NO	NO	19.51	19.51	NO	NO
2006	499.08	499.08	NO	NO	209.79	209.79	NO	NO	17.94	17.94	NO	NO
2007	495.96	495.96	NO	NO	203.49	203.49	NO	NO	17.95	17.95	NO	NO
2008	466.02	466.02	NO	NO	169.30	169.30	NO	NO	24.32	24.32	NO	NO
2009	437.09	437.09	NO	NO	128.66	128.66	NO	NO	22.50	22.50	NO	NO
2010	453.57	453.57	NO	NO	133.61	133.61	NO	NO	23.68	23.68	NO	NO
2011	471.94	471.94	NO	NO	123.86	123.86	NO	NO	28.53	28.53	NO	NO
2012	433.31	433.31	NO	NO	100.23	100.23	NO	NO	28.81	28.81	NO	NO
2013	409.16	409.16	NO	NO	101.59	101.59	NO	NO	31.88	31.88	NO	NO
2014	422.99	422.99	NO	NO	102.46	102.46	NO	NO	27.81	27.81	NO	NO
2015	394.53	394.53	NO	NO	122.80	122.80	NO	NO	29.71	29.71	NO	NO
Trend 2014-2015	-6.73%	-6.73%	NA	NA	19.85%	19.85%	NA	NA	6.83%	6.83%	NA	NA
Trend 1990-2015	-36.72%	-36.72%	NA	NA	-87.53%	-87.53%	NA	NA	36.13%	36.13%	NA	NA

2 - Industrial Processes														
GHG emissions by source & sink category (Gg CO_2 eq)														
Year	**2F-Product uses as substitutes for ODS**			**2G - Other product manufacture and use**					**2 - Industrial Processes**					
	Total	***HFCs***	***PFC***	**Total**	***HFC***	***PFC***	***SF6***	***N_2O***	**Total**	***CO_2***	***CH_4***	***N_2O***	***F-gases***
1990	0.00	0.00	*NO*	9.23	*NO*	*NO*	0.33	8.91	1 639.42	1 630.19	*NO*	8.91	0.33
1991	0.00	0.00	*NO*	8.93	*NO*	*NO*	0.35	8.58	1 560.76	1 551.83	*NO*	8.58	0.35
1992	13.69	13.69	*NO*	8.60	*NO*	*NO*	0.37	8.23	1 502.99	1 480.69	*NO*	8.23	14.06
1993	14.71	14.71	*NO*	8.31	*NO*	*NO*	0.40	7.91	1 480.45	1 457.42	*NO*	7.91	15.11
1994	16.04	16.04	*NO*	8.03	*NO*	*NO*	0.43	7.60	1 388.71	1 364.63	*NO*	7.60	16.47
1995	18.37	18.37	*NO*	8.67	*NO*	*NO*	1.39	7.29	1 031.48	1 004.43	*NO*	7.29	19.76
1996	20.14	20.14	*NO*	8.51	*NO*	*NO*	1.56	6.96	977.01	948.36	*NO*	6.96	21.70
1997	22.62	22.62	*NO*	8.32	*NO*	*NO*	1.70	6.63	869.74	838.80	*NO*	6.63	24.32
1998	25.06	25.06	*NO*	8.04	*NO*	*NO*	1.74	6.30	711.74	678.64	*NO*	6.30	26.81
1999	26.92	26.92	*NO*	7.78	*NO*	*NO*	1.83	5.96	750.71	716.01	*NO*	5.96	28.74
2000	29.73	29.73	*NO*	7.52	*NO*	*NO*	1.93	5.60	779.18	741.93	*NO*	5.60	31.65
2001	33.75	33.75	*NO*	7.76	*NO*	*NO*	2.54	5.22	725.84	684.34	*NO*	5.22	36.29
2002	36.65	36.65	*NO*	8.41	*NO*	*NO*	3.15	5.26	746.75	701.69	*NO*	5.26	39.80
2003	39.04	39.04	*NO*	8.82	*NO*	*NO*	3.73	5.09	694.05	646.19	*NO*	5.09	42.77
2004	41.12	41.12	*NO*	8.89	*NO*	*NO*	4.28	4.61	754.05	704.04	*NO*	4.61	45.40
2005	40.18	40.18	*NO*	9.12	*NO*	*NO*	4.85	4.27	725.53	676.23	*NO*	4.27	45.04
2006	43.27	43.27	*NO*	9.83	*NO*	*NO*	5.27	4.56	779.92	726.81	*NO*	4.56	48.54
2007	47.99	47.99	*NO*	10.58	*NO*	*NO*	5.69	4.89	776.19	717.62	*NO*	4.89	53.68
2008	50.51	50.51	*NO*	11.43	*NO*	*NO*	6.10	5.33	721.89	659.95	*NO*	5.33	56.61
2009	51.91	51.91	*NO*	11.18	*NO*	*NO*	6.49	4.69	651.68	588.59	*NO*	4.69	58.40
2010	54.26	54.26	*NO*	10.45	*NO*	*NO*	6.87	3.58	675.95	611.24	*NO*	3.58	61.13
2011	57.18	57.18	*NO*	10.72	*NO*	*NO*	7.31	3.42	692.63	624.73	*NO*	3.42	64.49
2012	59.62	59.62	*NO*	10.97	*NO*	*NO*	7.68	3.28	633.40	562.82	*NO*	3.28	67.30
2013	60.70	60.70	*NO*	13.59	2.56	*NO*	8.05	2.97	617.47	543.18	*NO*	2.97	71.32
2014	68.57	68.57	*NO*	13.30	1.71	*NO*	8.43	3.17	635.81	553.94	*NO*	3.17	78.71
2015	67.05	67.05	*NO*	13.93	1.99	*NO*	8.89	3.06	627.67	546.69	*NO*	3.06	77.92
Trend 2014-2015	*-2.22%*	*-2.22%*	*NA*	*4.74%*	*16.54%*	*NA*	*5.42%*	*-3.41%*	*-1.28%*	*-1.31%*	*NA*	*-3.41%*	*-1.00%*
Trend 1990-2015	*93773830.61%*	*95905789.51%*	*NA*	*44.08%*	*NA*	*NA*	*2619.39%*	*-65.64%*	*-61.71%*	*-66.46%*	*NA*	*-65.64%*	*23743.02%*

Source: Environment Agency

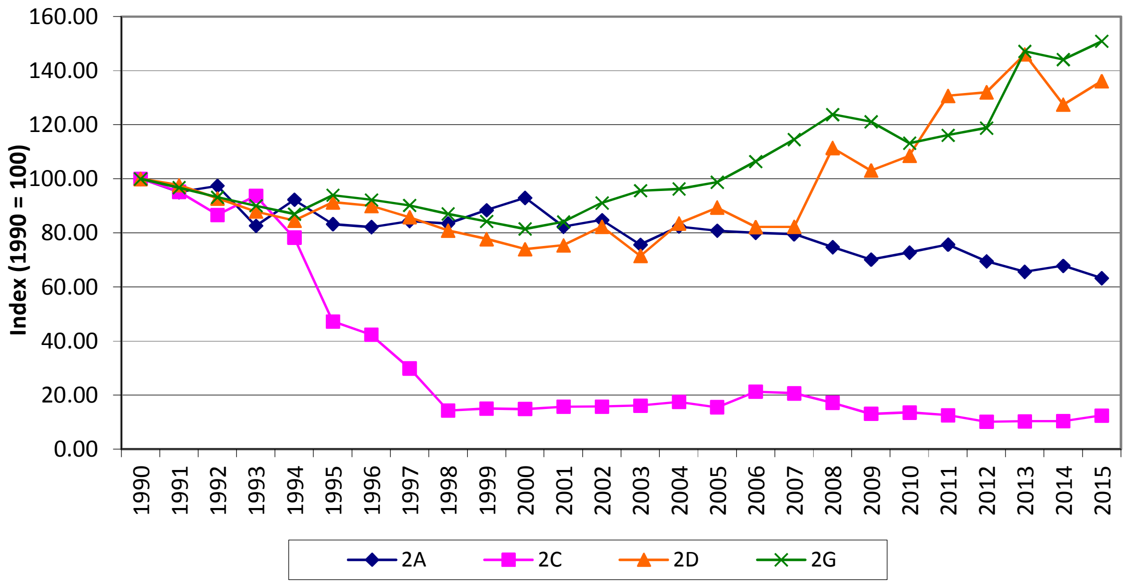
Notes:

CH_4 emissions are converted in CO_2e by multiplying the emissions by 21, *i.e.* the global warming potential (*GWP*) value for methane based on the effects of GHG over a 100-year time horizon.

N_2O emissions are converted in CO_2e by multiplying the emissions by 310, *i.e.* the global warming potential (*GWP*) value for nitrous oxide based on the effects of GHG over a 100-year time horizon.

The F-gases are those not covered by the Montreal Protocol, i.e. HFCs, PFCs and SF6 expressed in CO2e using the global warming potential (GWP) values based on the effects of GHG over a 100-year time horizon.

Figure 4-2 – GHG emission trends – indexes – for CRF Sector 2 – Industrial Processes: 1990-2015



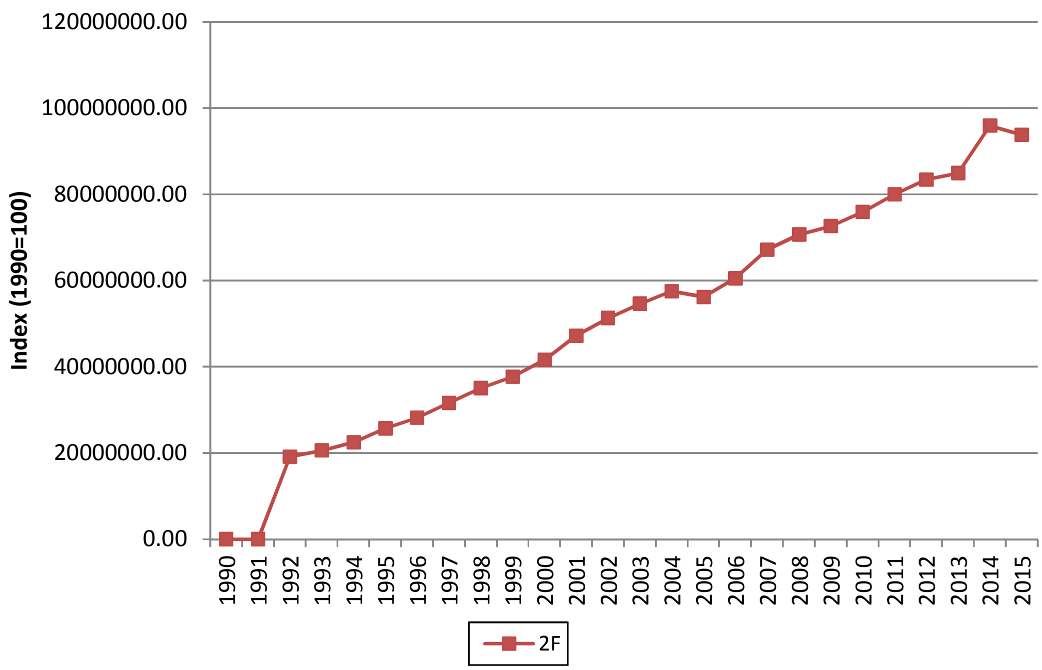
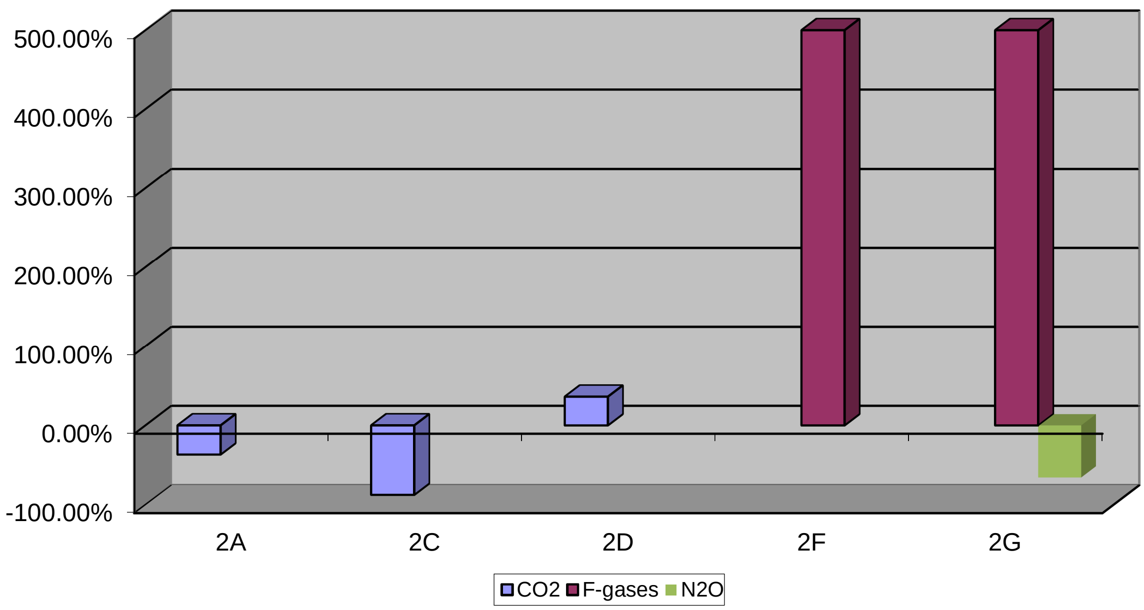


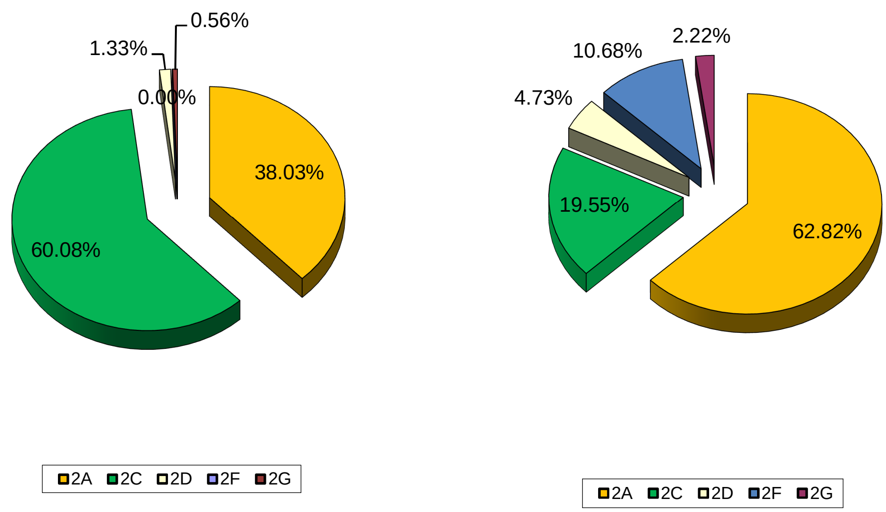
Figure 4-3 – GHG emission trends in % for CRF Sector 2 – Industrial Processes: 1990-2015



The emission trends briefly described above led to a significant change in the composition of industrial processes' GHG emissions, as shown in Figure 4-4.

Figure 4-4 – IPCC Categories weights in GHG emissions for CRF Sector 2 – Industrial Processes: 1990 and 2015

1990 *2015*



4.1.2 Key Categories

The methodology and results of the key source analysis are presented in Chapter 1. Table 4-2 presents the key source categories of IPCC Category 2 Industrial processes.

Table 4-2 – Key sources of IPCC category 2 - Industrial processes

2 - Industrial Processes and Product Use

Key sources

IPCC Category	Category Name	GHG	LA excl. LULUCF	LA incl. LULUCF	TA excl. LULUCF	TA incl. LULUCF
2A1	Cement Production	CO_2	90-15	90-15	X	
2A3	Glass Production	CO_2	00, 10, 14-15			
2C1	Iron & Steel Production	CO_2	90-15	90-95	X	
2F1	Refrigeration and air conditioi	F-gases	14			

Source: Environment Agency

Notes: LA = Level Assessement (Tier 1) including respectively exluding LULUCF

TA = Trend Assessement 2015 (Tier 1) including respectively exluding LULUCF

4.1.3 Completeness

Table 4-3 and Table 4-4 give an overview of the IPCC categories included under CRF Sector 2 and provide information on the status of emission estimates of all sub-categories.

Table 4-3 – Overview of sub-categories of CRF Sector 2 – Industrial Processes: status of emission estimates for CO_2, CH_4 and N_2O

GHG source & sink category	Description	Status		
		CO_2	CH_4	N_2O
2.A.1	mineral products - cement production	**X**		
2.A.2	mineral products - lime production	NO		
2.A.3	mineral products - glass production	**X**		
2.A.4	mineral products - other process uses of carbonates	NO		
2.A.4.a	Ceramics	NO		
2.A.4.b	Other uses of soda ash	NO		
2.A.4.c	Non-metallurgical magnesium production	NO		
2.A.4.d	Other	NO		
2.B.1	chemical industry - ammonia production	NO	NO	NO
2.B.2	chemical industry - nitric acid production			NO
2.B.3	chemical industry - adipic acid production	NO		NO
2.B.4	chemical industry - carbide production	NO	NO	
2.B.5	chemical industry - other	NO	NO	NO
2.B.4	chemical industry - caprolactam, glyoxal and glyoxylic acid production	NO	NO	NO
2.B.5	chemical industry - carbide production	NO	NO	NO
2.B.6	chemical industry - titanium dioxide production	NO	NO	NO
2.B.7	chemical industry - soda ash production	NO	NO	NO
2.B.8	chemical industry - petrochemical and carbon black production	NO	NO	NO
2.B.9	chemical industry - fluorochemical production	NO	NO	NO
2.B.10	chemical industry - other	NO	NO	NO
2.C.1	metal production - iron and steel production	**X**	NO	NO
2.C.1.a	Steel	**X**	NO	NO
2.C.1.b	Pig iron	NO	NO	NO
2.C.1.c	Direct reduced iron	NO	NO	NO
2.C.1.d	Sinter	NO	NO	NO
2.C.1.e	Pellet	NO	NO	NO
2.C.1.f	Other (please specify)	**NO**	NO	NO
2.C.2	metal production - ferroalloys production	NO	NO	NO
2.C.3	metal production - aluminium production	NO	NO	NO
2.C.4	metal production - magnesium production	NO	NO	NO
2.C.5	metal production - lead production	NO	NA	NA
2.C.6	metal production - zink production	NO	NO	NO
2.C.7	metal production - other	NO	NO	NO
2.D.1	non-energy products from fuels and solvent us - lubricant use	X		
2.D.2	non-energy products from fuels and solvent us - paraffin wax use	X		
2.D.3	non-energy products from fuels and solvent us - other	X		
2.D.3	solvent use	X	NO	NO
2.D.3	road paving with asphalt	NO	NO	NO

GHG source & sink category	Description	Status		
		CO_2	CH_4	N_2O
2.D.3	asphalt roofing	NO	NO	NO
2.D.3	other (please specify) Urea-based catalysts	X	NO	NO
2.G	other product manufacture and use	NO	NO	X
2.G.3	other product manufacture and use - N2O from product uses	NO	NO	X
2.G.3.a	Medical applications	NO	NO	X
2.G.3.b	other	NO	NO	X
	propellant for pressure and aerosol products	NO	NO	X
	other (please specify)	NO	NO	NO
2.H.1	other - pulp and paper	NO	NO	NO
2.H.2	other - food and beverages industry	NO	NO	NO
2.H.3	other - other (please specify)	NO	NO	NO

Note: A **X** indicates that emissions from this sub-category have been estimated, the grey shaded cells are those also shaded in the CRF tables.

Table 4-4 – Overview of subcategories of CRF Sector 2 – Industrial Processes: status of emission estimates for halocarbons, SF_6 and NF_3

GHG source & sink category	Description	Status			
		HFCs	PFCs	SF_6	NF_3
2.B	chemical industry	NO	NO	NO	NO
2.B.9	fluorochemical production	NO	NO	NO	NO
	by-product emissions	NO	NO	NO	NO
	fugitive emissions	NO	NO	NO	NO
2.B.10	other	NO	NO	NO	NO
2.C	metal industry	NO	NO	NO	NO
2.C.3	aluminium production	NO	NO	NO	NO
2.C.4	magnesium production	NO	NO	NO	NO
2.C.7	other	NO	NO	NO	NO
2.E	electronics industry	NO	NO	NO	NO
2.E.1	integrated circuit or semiconductor	NO	NO	NO	NO
2.E.2	TFT flat panel display	NO	NO	NO	NO
2.E.3	photovoltaics	NO	NO	NO	NO
2.E.4	heat transfer fluid	NO	NO	NO	NO
2.E.5	other	NO	NO	NO	NO
2.F	product uses as substitutes for ODS	X	NO	X	NO
2.F.1	refrigeration and air conditioning	X	NO	NO	NO
2.F.2	foam blowing agents	X	NO	NO	NO
2.F.3	fire protection	NO	NO	NO	NO
2.F.4	aerosols	X	NO	NO	NO
2.F.5	solvents	NO	NO	NO	NO
2.F.6	other applications	NO	NO	NO	NO
2.G	other product manufacture and use	X	NO	X	NO
2.G.1	electrical equipment	NO	NO	X	NO
2.G.2	SF6 and PFCs from other product use	NO	NO	X	NO
2.G.4	other	X	NO	NO	NO
2.H.1	other - pulp and paper	NO	NO	NO	NO
2.H.2	other - food and beverages industry	NO	NO	NO	NO
2.H.3	other - other (please specify)	NO	NO	NO	NO

Note: a **X** indicates that emissions from this sub-category have been estimated, the grey shaded cells are those also shaded in the CRF tables.

4.2 Mineral Products (2.A.)

This section describes the estimation of carbon dioxide emissions resulting from industrial processes used in clinker works and flat glass production installations. In 2015, this source category was responsible for 72.17% of GHG emissions in CO2e from industrial processes – but only 38.24% in 1990 – and for 3.84% of the total CO_2 emissions estimated for Luxembourg. It represented 3.51% of the total GHG emissions in CO_2e (excluding LULUCF) in 2015 and 4.89% in 1990. Compared to 2014, emissions decreased by 6.37% to attain the level of 394.53Gg CO_2 in 2015. Compared to 1990, emissions decreased by 36.72%.

4.2.1 Cement Production (2.A.1)

4.2.1.1 Source category description

In 2015, clinker production was responsible for 60.27% of GHG emissions in CO2e from industrial processes – but only 34.96% in 1990 – and for 3.21% of the total CO_2 emissions estimated for Luxembourg. It represented 2.93% of the total GHG emissions in CO_2e (excluding LULUCF). Compared to 2014, emissions decreased by 8.36% to attain the level of 329.47 Gg CO_2 in 2015. Compared to 1990, emissions decreased by 42.19%.

2A1 - Cement Production is a key source with regard to CO_2 emissions. It has been a key source without interruption since 1990: see Table 4-2 in Section 4.1.2.

4.2.1.2 Methodological issues

4.2.1.2.1 Activity data

In Luxembourg, one clinker production plant is operating. During the production of clinker, limestone, which is mainly calcium carbonate ($CaCO_3$), is calcined to produce lime (CaO) and CO_2 as a by-product.

Activity data, *i.e.* clinker production, is obtained annually from the plant operator (Table 4-5).

4.2.1.2.2 Methodology

1990-2013: For the estimation of CO_2 emissions, the ETS 2007 method using clinker production data is applied:

$$CO_2\ Emissions = EF_{clinker} \bullet CF_{clinker} \bullet Clinker\ Production$$

The conversion factor ($CF_{clinker}$) takes into account the amount of (non-carbonate) CaO and MgO in the raw materials. According to the operator of the plant, there is no calcined Cement Kiln Dust (*CKD*) to be lost from the system.

According to 2007 ETS Tier 3 method, the emission factor is based on the CaO and MgO content of the clinker:

$$EF_{clinker} = 0.785 \bullet \text{CaO Content} + 1.092 \bullet \text{MgO Content (Weight Fraction in Clinker)}$$

The CaO and MgO contents for the years for which no CaO and no MgO contents are available, are estimated by a linear interpolation (Table 4-6).

Starting 2014, emissions associated to dust in the production ovens have been determined by the operating company. Similar to previous years, the previously described approach according to ETS guidelines is applied and the following fluxes are considered:

-fluxes resulting from process generated dusts in the rotatif oven

-fluxes associated with used powders in the rotatif oven

Table 4-5 – CO_2 emissions trend, activity data and IEFs for IPCC sub-category 2A1 – Cement Production: 1990-2015

2A1 - Clinker Production			
Activity data, emissions and implied emission factors			
Year	AD	CO_2	IEF
	t	*Gg*	*kg CO_2 / t clinker*
1990	1048 000	569.88	543.78
1991	1001 637	544.10	543.21
1992	1013 452	549.88	542.58
1993	842 855	456.79	541.95
1994	950 854	514.72	541.33
1995	848 455	458.76	540.70
1996	837 518	452.38	540.14
1997	865 659	467.09	539.58
1998	870 053	468.98	539.02
1999	913 265	491.76	538.47
2000	965 369	519.28	537.91
2001	843 608	452.71	536.64
2002	874 577	468.22	535.37
2003	769 754	411.12	534.10
2004	847 389	451.51	532.83
2005	833 798	443.21	531.56
2006	826 131	438.74	531.08
2007	816 688	433.34	530.60
2008	761 816	403.86	530.13
2009	708 048	378.06	533.94
2010	736 019	391.49	531.90
2011	770 232	411.12	533.76
2012	758 241	374.86	494.38
2013	743 260	365.43	491.66
2014	731 076	359.55	483.55
2015	677 731	329.47	474.95
Trend 2014-2015	-7.30%	-8.36%	-1.78%
Trend 1990-2015	-35.33%	-42.19%	-12.66%

4.2.1.2.3 Emission factor

Emission estimates from the Tier 2 method, as well as activity data and IEFs, are summarized in Table 4-5.

Table 4-6 – Effective and interpolated CaO content in % and EFs: 1990-2015

2A1 - Cement Production						
CaO content & emission factors						
Year	**CaO (%)**	**CaO (%)**	**MgO (%)**	**MgO (%)**	**EF**	**CF**
	operator	***interpolation***	***operator***	***interpolation***	***kg CO_2 / t clinker***	**-**
1990	67.72	67.72	1.12	1.12	543.78	1.00
1991		67.67		1.10	543.21	1.00
1992		67.62		1.08	542.58	1.00
1993		67.56		1.06	541.95	1.00
1994		67.51		1.04	541.33	1.00
1995	67.46	67.46	1.02	1.02	540.70	1.00
1996		67.40		1.01	540.14	1.00
1997		67.34		1.00	539.58	1.00
1998		67.28		1.00	539.02	1.00
1999		67.22		0.99	538.47	1.00
2000	67.16	67.16	0.98	0.98	537.91	1.00
2001		67.03		0.96	536.64	1.00
2002		66.89		0.94	535.37	1.00
2003		66.76		0.92	534.10	1.00
2004		66.62		0.90	532.83	1.00
2005	66.49	66.49	0.88	0.88	531.56	1.00
2006		66.42		0.89	531.08	1.00
2007		66.35		0.89	530.60	1.00
2008	66.28	66.28	0.90	0.90	530.13	1.00
2009	66.78	66.78	0.89	0.89	533.94	1.00
2010	66.59	66.59	0.84	0.84	531.90	1.00
2011	66.84	66.84	0.83	0.83	531.90	1.00
2012	65.93	65.93	1.22	1.22	530.87	0.93
2013	65.93	65.93	1.22	1.22	530.87	0.93
2014	67.11	67.11	1.43	1.43	542.43	0.89
2015	67.17	67.17	1.86	1.86	547.60	0.87
Sources: plant operator and Environment Agency						

4.2.1.2.4 Conversion factor (CF)

In 2013, the raw material composition was changed so that it can no longer be assumed that all the CaO and MgO in the clinker are from carbonate source (*e.g.* $CaCO_3$ and $MgCO_3$ in limestone). To take into account the amount of (non-carbonate) CaO and MgO in the raw material and according to 2007 ETS method, the conversion factor (CF) is based on measurements twice a month of total carbon, organic carbon, CaO and MgO content in the raw material.

4.2.1.3 Uncertainties and time-series consistency

The following input uncertainties are assumed:

- Activity data uncertainty .... 1 %
- Emission factor uncertainty .... 2.5 %

These numbers are based on the uncertainties available at plant-level in the frame of the ETS.

The time series is considered as consistent.

4.2.1.4 Source-specific QA/QC and verification

The calculated plant-specific emission factors are consistent with the 2004 ETS Tier 1 Guidelines default emission factor of 525 kg CO_2/t clinker.

4.2.1.5 Category-specific recalculations including changes made in response to the review process

The value for CO2 emissions for the year 2014 has been revaluated. A detailed description is given in the methodology part.

Consistency of the figures reported in the NIR and the CRF tables was ensured (ARR 2013, §38).

4.2.1.6 Category-specific planned improvements including those in response to the review process

There are no planned improvements to IPCC sub-category 2.A.1.

4.2.2 Lime Production (2.A.2)

This source category does not exist in Luxembourg.

4.2.3 Glass Production (2.A.3)

4.2.3.1 Source category description

In 2015, glass production was responsible for 11.90% of GHG emissions in CO_2e from industrial processes – but only 3.29% in 1990 – and for 0.63% of the total CO_2 emissions estimated for Luxembourg. It represented 0.58% of the total GHG emissions in CO_2e (excluding LULUCF). Compared to 2014, emissions increased by 2.55% to attain the level of 65.06 Gg CO2 in 2015. Compared to 1990, emissions increased by 21.45%.

2.A.3 - Glass Production is a key source with regard to CO_2 emissions. It has been a key source since 1995: see Table 4-2 in Section 4.1.2.

4.2.3.2 Methodological issues

4.2.3.2.1 Activity data

In Luxembourg, one company runs two flat glass production plants. CO_2 is released during melting in the kiln, from carbonates contained in mineral input materials (limestone, dolomite and soda ash).

Activity data, *i.e.* flat glass production, is obtained annually from the plant operators (Table 4-7).

4.2.3.2.2 Methodology

A country specific (CS) methodology is applied:

$$CO_2 \text{ emissions} = EF_{glass} \bullet \text{Glass Production}$$

Estimates from the CS method, as well as activity data and IEFs, are summarized in Table 4-7.

The use of soda ash for glass production is account for in 2A7. The amount of soda ash used in 2014 in the glass production was 71554 t (Source: verified ETS data). In 2015, the use of soda ash amounted to 74434.09 t.

Table 4-7 – CO_2 emission trend, activity data and IEFs for IPCC sub-category 2.A.3 – Other – Glass Production: 1990-2015

2A3 - Glass Production *Activity data, emissions and implied emission factors*			
Year	**AD**	**CO_2**	**IEF**
	t	***Gg***	***kg CO_2 / t glass***
1990	377 240	*53.57*	*142.00*
1991	342 745	*48.67*	*142.00*
1992	403 328	*57.27*	*142.00*
1993	410 176	*58.24*	*142.00*
1994	426 991	*60.63*	*142.00*
1995	425 026	*60.35*	*142.00*
1996	420 750	*59.75*	*142.00*
1997	414 616	*58.88*	*142.00*
1998	361 401	*51.32*	*142.00*
1999	419 579	*59.58*	*142.00*
2000	425 751	*60.46*	*142.00*
2001	425 391	*60.41*	*142.00*
2002	423 240	*60.10*	*142.00*
2003	426 299	*60.53*	*142.00*
2004	435 595	*61.85*	*142.00*
2005	435 073	*60.59*	*139.27*
2006	435 806	*60.34*	*138.45*
2007	443 094	*62.63*	*141.34*
2008	440 538	*62.16*	*141.10*
2009	437 319	*59.03*	*134.99*
2010	430 140	*62.07*	*144.31*
2011	433 676	*60.82*	*140.24*
2012	423 081	*58.45*	*138.15*
2013	304 453	*43.74*	*143.66*
2014	430 098	*63.44*	*147.51*
2015	420 703	*65.06*	*154.65*
Trend 2014-2015	*-2.18%*	*2.55%*	*4.84%*
Trend 1990-2015	*11.52%*	*21.45%*	*8.91%*
Sources: AD: plant operator ; CO2 and IEF: Environment Agency			

4.2.3.2.3 Emission factors

The emission factor is based on the loss of ignition of the batch composition. Recycled glass is included in the calculation of the emission factor. The background data and the calculation of the emission factor are provided by the operator. The batch is composed of 1 t dry raw material and 0.25 t recycled glass. The loss of ignition of the dry raw material is 15.5%. Accordingly, the production of 1 t glass consumes 0.9132 t dry raw material and releases 141.5 kg CO_2 as loss of ignition. For each year, the plant-specific EF's of the two operating plants were determined based on the carbonate contents in the raw materials and the activity data for plant 1 and plant 2. The employed EF corresponds to the average EF of the two plants.

As no data is available for the years 1990-2004, an average EF of 142 kg CO2/ t glass, based on the years 2005-2013, has been applied for those years. There is no indication of any change in product quality or batch composition over time, hence favouring the approach of an average emission factor that is kept constant for the whole time span from 1990-2004.

4.2.3.3 Uncertainties and time-series consistency

The following input uncertainties are assumed:

- Activity data uncertainty .... 2 %
- Emission factor uncertainty .... 2 %

These uncertainties are relatively small because detailed information at plant-level is available via the operators' annual reports and reporting in the frame of ETS.

4.2.3.4 Source-specific QA/QC and verification

The calculated CO_2 emissions are consistent with the calculated value according to the ETS methodology.

Concerning the use of soda ash in glass production, import and export values for Soda ash, provided by STATEC, have been compared to the use of soda ash in Glass Production to check for equivalence and exclude any other application. See also 1.2.5.2 Other Uses of Soda ash (2.A.4.b)

4.2.3.5 Category-specific recalculations including changes made in response to the review process

For the years 2005-2014, EFs were revaluated. Previously a constant EF of 142 had been applied for the years 2005-2013. For the years 2014 and 2015, the actual EFs were differing strongly from the previously employed EF of 142. Thus, it was decided to determine and apply the actual EF for the years 2005-2015. A more detailed description is given in the methodology description.

4.2.4 Category-specific planned improvements including those in response to the review process

There are no planned improvements to IPCC sub-category 2.A.3.

4.2.5 Other Process Uses of Carbonates (2.A.4)

This source category does not exist in Luxembourg.

4.2.5.1 Ceramics (2.A.4.a)

This source category does not exist in Luxembourg.

4.2.5.2 Other Uses of Soda ash (2.A.4.b)

The use of soda ash is accounted for in IPCC sub-category *2A3 –Glass Production*. There is no other soda ash use in Luxembourg.

4.2.5.3 Source-specific QA/QC and verification

Import and Export values for Soda ash, provided by STATEC, have been compared to the use of soda ash in IPCC sub-category 2A3 –Glass Production to check for equivalence.

4.2.5.4 Non Metallurgical Magnesia Production (2.A.4.c)

This source category does not exist in Luxembourg.

4.2.5.5 Other (2.A.4.d)

This source category does not exist in Luxembourg.

4.2.6 Asphalt Roofing (2.A.5)

This source category does not exist in Luxembourg.

4.2.7 Road Paving with Asphalt (2.A.6)

This source category does not exist in Luxembourg.

4.3 Chemical Industry (2.B)

There are no emissions to be reported for the chemical industry for Luxembourg.

CRF	Description	Notation key
2.B.1	Ammonia production	NO
2.B.2	Nitric acid production	NO
2.B.3	Adipic acid production	NO
2.B.4	Caprolactam, glyoxal and glyoxylic acid production	NO
2.B.5	Carbide production	NO
2.B.6	Titanium dioxide production	NO
2.B.7	Soda ash production	NO
2.B.8	Petrochemical and carbon black production	NO
2.B.9	Fluorochemical production	NO
2.B.10	Other	NO

4.4 Metal Production (2.C)

This section describes the estimation of carbon dioxide emissions resulting from industrial processes relating to iron and steel production (IPCC Sub-category 2C1). As a matter of fact, steel production combines process and energy related emissions. For pragmatic reasons (and to be as close as reasonable to the real situation), gaseous fuels have been considered causing energy related emissions[108] (this includes blast furnace gas derived from solid fuels), and solid fuels (coke, anthracite, residue oil and – for electric arc furnaces – carbon electrodes) process related emissions.

No other IPCC sub-categories under IPCC category *2C* are reporting GHG emissions, hence IPCC category *2C* = IPCC sub-category *2C1 – Iron and Steel Production*.

4.4.1 Iron and Steel Production (2.C.1)

4.4.1.1 Source category description

In 2015, iron and steel production was responsible for 22.46% of GHG emissions in CO_2e from industrial processes – but 60.42% in 1990 – and for 1.20% of the total CO_2 emissions estimated for Luxembourg. It represented 1.09% of the total GHG emissions in CO_2e (excluding LULUCF). Compared to 2014, emissions increased by 19.85% to attain the level of 122.80 Gg CO_2 in 2015. Compared to 1990, emissions decreased by 87.53% due to the technological shift from blast furnaces to electric arc furnaces operated in the mid-1990s. Furthermore, one of three electric furnaces stopped production in the year 2012.

An overview of the iron and steel related CO_2 emissions is provided in Table 4-8.

108 Accounted for under IPCC Category 1A – Fuel Combustion Activities. See also Section 4.4.1.3 below.

Table 4-8 – CO_2 emissions trend, activity data and IEFs for IPCC sub-category 2C1 – Iron and Steel Production: 1990-2015

2C1 - Iron & Steel Production *Emissions, AD, IEFs*					
Year	**CO_2 (Gg)**	**BOF (t)**	**EAF (t)**	**Total (t)**	**IEF kg CO_2/t steel**
1990	984.91	*3506 230*	*NO*	3506 230	280.90
1991	937.74	*3379 440*	*NO*	3379 440	277.48
1992	853.29	*3068 463*	*NO*	3068 463	278.08
1993	923.19	*3288 847*	*4 095*	3292 942	280.36
1994	770.83	*2627 278*	*445 990*	3073 268	250.82
1995	465.38	*1410 469*	*1202 668*	2613 137	178.09
1996	416.60	*1168 070*	*1333 758*	2501 828	166.52
1997	294.10	*597 814*	*1982 405*	2580 219	113.98
1998	140.69	*NO*	*2476 909*	2476 909	56.80
1999	147.70	*NO*	*2600 324*	2600 324	56.80
2000	146.05	*NO*	*2571 243*	2571 243	56.80
2001	154.76	*NO*	*2724 679*	2724 679	56.80
2002	155.40	*NO*	*2736 000*	2736 000	56.80
2003	151.94	*NO*	*2675 000*	2675 000	56.80
2004	152.45	*NO*	*2684 000*	2684 000	56.80
2005	119.13	*NO*	*2194 485*	2194 485	54.29
2006	170.49	*NO*	*2802 049*	2802 049	60.85
2007	162.22	*NO*	*2845 872*	2845 872	57.00
2008	134.69	*NO*	*2584 341*	2584 341	52.12
2009	112.66	*NO*	*2103 281*	2103 281	53.56
2010	133.61	*NO*	*2633 613*	2633 613	50.73
2011	123.86	*NO*	*2525 697*	2525 697	49.04
2012	100.23	*NO*	*2208 000*	2208 000	45.39
2013	101.59	*NO*	*2089 000*	2089 000	48.63
2014	102.46	*NO*	*2192 999*	2192 999	46.72
2015	122.80	NO	*2126283*	2126 283	57.75
Sources: AD: plant operator ; Statec					
Note: STATEC's 1990 value for BOF replaced by TÜV Rheinland 1992-1993 study reported value.					

2C1 – Iron and Steel Production is a key source with regard to CO_2 emissions. It has been a key source since 1990: see Table 4-2 in Section 4.1.2.

4.4.1.2 Methodological issues

4.4.1.2.1 Activity data

One sinter plant, two blast furnaces and three basic oxygen furnace steel plants (*BOF*) were operated in Luxembourg in 1990. The shift from BOF steel production to the EAF steel production occurred between 1993 and 1997 (see Figure 4-5). Three electric arc furnaces were operated between 1998 and 2011. One advanced multiple-heath furnace followed by a specially designed electric arc furnace (PRIMUS process) was operated between 2003 and 2009. Since 2013 , only two of the three electric arc furnaces (*EAF*) are in operation.

A simplified country-specific methodology is used for the years 1993 to 2003 (as the first EAF was only introduced in 1993). It is important to mention that the base year 1990 is not concerned by this simplified methodology. In 1990, only blast furnaces were operated. Concerning time-series consistency, it is not possible to improve time-series consistency without losing the quality of the data. Indeed, the production processes changed over time and also more detailed methodologies were introduced over time which required a more detailed data collection. The required data for the time before the new methodologies do not exist, and cannot be extrapolated based on surrogates, without considerably increasing the uncertainties. Thus, it was opted to use the most detailed and verified data available to assess the emissions over time. In that sense, Luxembourg considers that the time series are constituent in an overall manner, as the carbon mass balance method was used for every technology used over time.

Concerning carbon mass balance, the NIR clearly indicates that for all production processes (BF, EAF, PRIMUS) a carbon mass balance is applied over the production process (NIR pages 255-259). For the example of the electric arc furnace production, the carbon mass balance is the following:

E= (CCarbon+CAnthracite) * 3.664 + EElectrodes+EPig iron+EPetroleum coke+ECaC2+Eflux

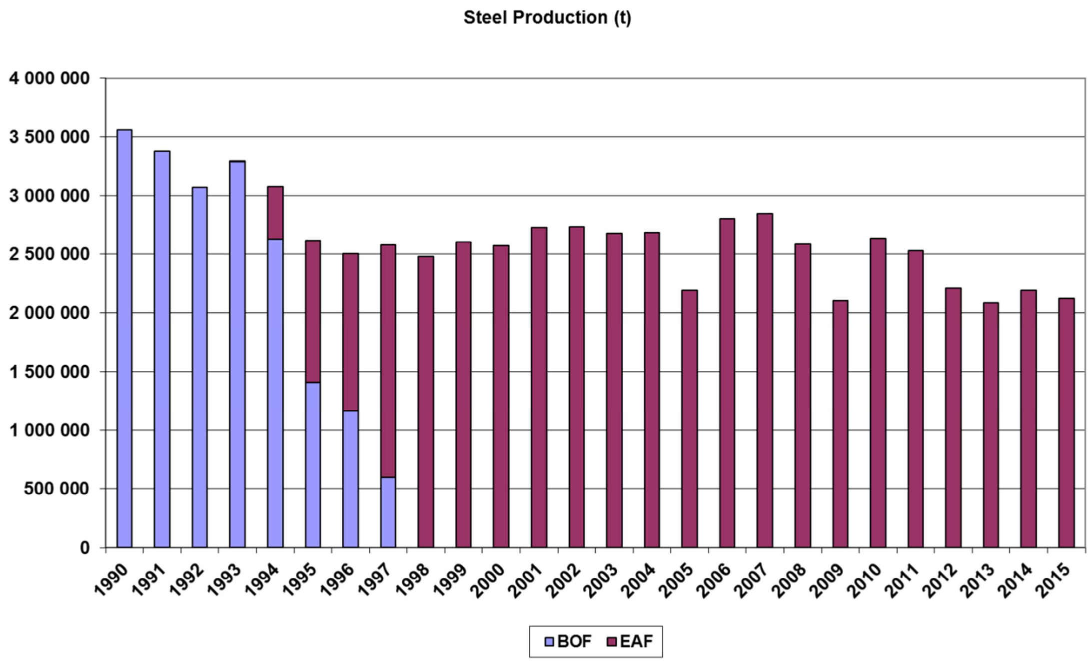
Ei= ADi * EFi   with i= electrodes, pig iron, petroleum coke, CaC2, fluxes

All materials introduced in the furnace and containing carbon are considered (carbon, anthracite, electrodes, pig iron, petroleum coke, CaC2 and scrap) and it is assumed that the carbon content of the steel output equals to the scrap input.

Limestone and dolomite were not used as such in Luxembourg's BF and BOF steel production. In the sinter plant, the sinter was produced from two types of iron ore, "Minettes calcaires", i.e. iron ore containing carbonates and "Minettes silicieuses", i.e. siliceous iron ore. The carbon content of the iron ore is displayed in Table 4-10. The use of carbonate containing iron ore, and mixing it with siliceous ore, was advantageous in the sense that no limestone needed to be added to reach the optimal basicity of the final ore. Hence, decarbonisation of the ore is considered in the sinter plant and neither limestone nor dolomite was added to the ore to produce the agglomerate.

In the BF and BOF steel production, again neither limestone nor dolomite was added to the production process. Only burnt lime is used in the BOF steel production, for instance, to favour the slagging. All the C input is detailed in the methodological description.

Figure 4-5 – Steel production according to BOF and EAF: 1990-2015



Several plants are considered:

Sinter Plant (SP)

In the sinter plant iron ore and other iron-containing materials are agglomerated prior to the introduction into the blast furnace. Process emissions occur from the oxidation of the carbonates in the iron ore.

Blast furnace (BF)

Mainly sinter (iron oxides), coke and other fuels are supplied to the blast furnace. CO_2 process emissions are associated with the use of carbon to convert iron oxide to pig iron. Coke and other fuels serve not only as reducing agent but also to produce blast furnace gas as energy source which is recovered and used as fuel within the plant and in other steel industry processes and in a power station.

An energy balance serves to exclude double-counting of carbon from the consumption as reducing agent if this is already accounted for as fuel consumption in IPCC category *1A – Fuel Combustion Activities*.

Basic oxygen furnace steel production (BOF)

In the basic oxygen furnace, pig iron (4% C) is transformed to steel (0.13% C). During the process, the reduced carbon is released as CO_2.

Electric arc furnace steel production (EAF)

In the electric arc furnaces anthracite and carbon, including the consumption of the electrodes, are used as reducing agent with the result of CO_2 process emissions. The consumption of natural gas in the EAF is accounted for as energy consumption and, consequently, reported under IPCC Sub-category *1A2a – Iron and Steel*.

PRIMUS® process (PRIMUS)

The PRIMUS process consists of a combination of an advanced multiple-heath furnace and a specially designed electric arc furnace. Steelmaking dust is transformed into iron. Process emissions occur from raw material (steelmaking dust) and reducing agents (anthracite, carbon and the consumption of the electrodes).

Activity data for iron production (*BF*) and steel production (*BOF & EAF*) are collected from STATEC's Statistical Yearbook. They have been supplemented by information received directly from the operator. This is the case for sinter production (*SP*) and for the steel production breakdown between BOF & EAF between 1993 and 1997.

The activity data for the PRIMUS® process is based on the introduced filter dust.

The production data for the steel production in 1990 (*BOF*) was corrected based on detailed information from the TÜV Rheinland 1992-1993 study. It is assumed that the 1990 value of 3 560 290 tonnes for BOF in STATEC's Statistical Yearbook is a typing error.

Table 4-9 summarizes iron and steel production by process.

Table 4-9 – Iron and steel production by process: 1990-2015

2C1 - Iron & Steel Production *Emissions, AD, IEFs*					
Year	**CO_2 (Gg)**	**BOF (t)**	**EAF (t)**	**Total (t)**	**IEF kg CO_2/t steel**
1990	984.91	*3506 230*	*NO*	3506 230	280.90
1991	937.74	*3379 440*	*NO*	3379 440	277.48
1992	853.29	*3068 463*	*NO*	3068 463	278.08
1993	923.19	*3288 847*	*4 095*	3292 942	280.36
1994	770.83	*2627 278*	*445 990*	3073 268	250.82
1995	465.38	*1410 469*	*1202 668*	2613 137	178.09
1996	416.60	*1168 070*	*1333 758*	2501 828	166.52
1997	294.10	*597 814*	*1982 405*	2580 219	113.98
1998	140.69	*NO*	*2476 909*	2476 909	56.80
1999	147.70	*NO*	*2600 324*	2600 324	56.80
2000	146.05	*NO*	*2571 243*	2571 243	56.80
2001	154.76	*NO*	*2724 679*	2724 679	56.80
2002	155.40	*NO*	*2736 000*	2736 000	56.80
2003	151.94	*NO*	*2675 000*	2675 000	56.80
2004	152.45	*NO*	*2684 000*	2684 000	56.80
2005	119.13	*NO*	*2194 485*	2194 485	54.29
2006	170.49	*NO*	*2802 049*	2802 049	60.85
2007	162.22	*NO*	*2845 872*	2845 872	57.00
2008	134.69	*NO*	*2584 341*	2584 341	52.12
2009	112.66	*NO*	*2103 281*	2103 281	53.56
2010	133.61	*NO*	*2633 613*	2633 613	50.73
2011	123.86	*NO*	*2525 697*	2525 697	49.04
2012	100.23	*NO*	*2208 000*	2208 000	45.39
2013	101.59	*NO*	*2089 000*	2089 000	48.63
2014	102.46	*NO*	*2192 999*	2192 999	46.72
2015	122.80	NO	*2126283*	2126 283	57.75
Sources: AD: plant operator ; Statec					
Note: STATEC's 1990 value for BOF replaced by TÜV Rheinland 1992-1993 study reported value.					

4.4.1.2.2 Methodology

Sinter Plant (SP)

The emissions in 1990 are calculated from the mass of carbon in the ore. It is therefore a country specific methodology. The data were collected directly from the operator.

Table 4-10 – Background data for the calculation of CO_2 emissions – Sinter Plant

Raw material	Tonnes (dry)	% C	Gg CO_2
Minettes calcaires	2 043 408	4.38	328.16

Minettes silicieuses	908 957	1.57	52.27
Total	2 952 365	NA	380.43

A country specific methodology has been applied for the years 1991 to 1997 based on the emission factor determined for the year 1990:

$$CO_2\ Emissions_{SP} = EF_{SP} \bullet Sinter\ Production$$

Blast furnace (BF) and basic oxygen furnace steel production (BOF)

The 2000 IPCC-GPG Tier 2 methodology is applied for calculating the emissions in 1990.

The emissions from iron production in BF and from steel production in BOF are calculated separately based on a carbon balance over the production processes.

$$Emissions_{BF} = E_{Iron} = (C_{Reducing\ Agent} + C_{Ore} - C_{Iron}) \bullet 44/12$$

$$Emissions_{BOF} = E_{Steel} = (C_{Iron} + C_{Scrap} + C_{AddBOF} - C_{Steel}) \bullet 44/12$$

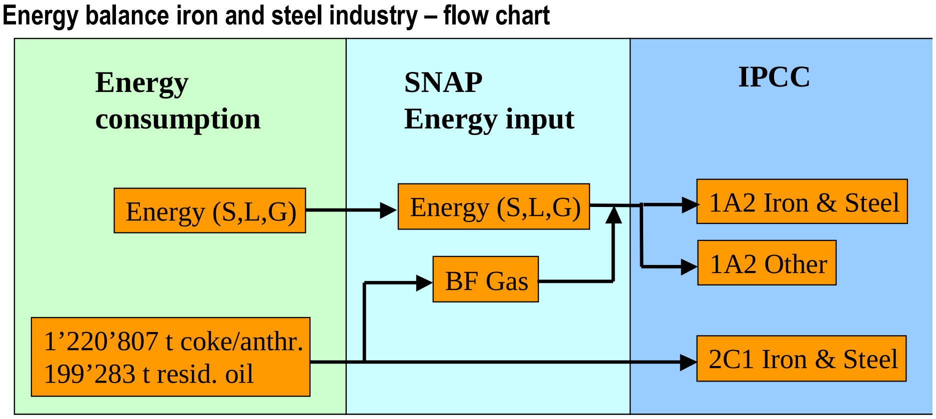
With:

$C_{Reducing\ Agent}$	= carbon serving as reducing agent: calculated from the energy balance over the iron and steel production, see below
C_{Ore}	= additional C-input from Iron ore and Iron scrap into the BF: 3 841 t iron ore (1.57% C, plant specific) + 6 222 t iron scrap (4% C, IPCC default)
C_{Iron}	= 2 645 200 t Iron (4% C, IPCC default)
C_{Scrap}	= 1 296 470 t Steel Scrap (0.4%, ETS default)
C_{AddBOF}	= Additional C-input in BOF: 19 532 t Ferromangan (4% C, plant specific), 1 688 t Carbon 95 (95% C, plant specific), 2 671 t Carbon 98 (98% C, plant specific)
C_{Steel}	= 5 506 230 t Steel (0.13% C, plant specific)

Activity data, as indicated above, were collected from the operator [TÜV Rheinland, 1992-1993].

The carbon accounted for reducing agent ($C_{Reducing\ Agent}$) in the blast furnace is determined from the energy balance over the iron and steel industry.

Figure 4-6 – Energy balance iron and steel industry – flow chart



In 1990, the overall energy consumption in the iron and steel industry was compared with the energy input into the different SNAP categories reported in the CORINAIR inventory. 1 180 646 t coke, 40 027 t anthracite and 199 283 t residual oil are accounted to be transformed partly into blast furnace gas which is then fed with the remaining solid, liquid and gaseous fuels into the CORINAIR SNAP categories and further on into the different IPCC Energy sub-categories 1A2a and 1A2f. The remaining part of the blast furnace gas carbon serves as reducing agent that is reported under IPCC sub-category 2C1:

$$C_{Reducing\ Agent} = C_{2C1} = C_{(1\ 220\ 807\ t\ coke/anthracite\ +\ 199\ 283\ t\ residual\ oil)} - C_{BFGas}$$

From the 1990 energy balance (Table 4-11), 160.05 Gg carbon (*C*) serves as reducing agent in the blast furnace.

Table 4-11 – Energy balance iron and steel industry: 1990

Energy	tonnes	% C		Gg C
Coke	1 180 646	90.33		1066.48
Anthracite	40 027	95.00		38.03
Oil	199 283	85.75		170.88
Energy	**GJ**	**kg CO_2/ GJ**	**kg C/ GJ**	**Gg C**
BFGas	15 851 000	258.00	70.36	1115.33
				Gg C
C Reducing Agent				160.05

Therefore, the resulting carbon dioxide emissions for the iron and steel production in 1990 equal:

$$CO_2\ Emissions_{BF} = 200.00\ Gg\ CO_2$$

$$CO_2\ Emissions_{BOF} = 404.48\ Gg\ CO_2$$

For the subsequent years (1991 to 1997), a country specific methodology has been applied based on the emission factor determined for the year 1990:

$$CO_2\ Emissions_{BF} = EF_{BF} \bullet Pig\ Iron\ Production$$

$$CO_2\ Emissions_{BOF} = EF_{BOF} \bullet Steel\ Production$$

Electric arc furnace steel production (EAF)

The mass balance approach according to 2007 ETS guidelines is applied for calculating the emissions for the years 2004 to 2014.

The emissions are calculated based on a carbon balance over the production process.

$$E= (C_{Carbon}+C_{Anthracite}) \bullet 3.664 + E_{Electrodes}+E_{Pig\ iron}+E_{Petroleum\ coke}+E_{CaC2}+E_{Scrap}- E_{Steel}$$

$$E_i= AD_i \bullet EF_i \quad \text{with } i = \text{electrodes, pig iron, petroleum coke, CaC2}$$

It is assumed that E_{Scrap} equals E_{Steel}.

The activity data (C_{Carbon} , $C_{Anthracite}$, AD_i) are collected from the individual EAF (consumption of carbon, anthracite, electrodes, pig iron, petroleum coke and calcium carbide with their respective carbon contents).

The emission factors (EF) for electrodes, pig iron, petroleum coke and calcium carbide are taken from the 2007 guidelines - Tier1.

Starting 2015, better data collection allowed for a more specific approach regarding the calculations of EAF associate emissions. Similar to previous years, the mass balance approach, according to 2007 ETS guidelines, is applied, while the carbon balance over the production process has been expanded on:

$$E= (C_{Carbon}+C_{Anthracite}) \bullet 3.664 + E_{Electrodes}+E_{Pig\ iron}+E_{Petroleum\ coke}+E_{CaC2}+E_{flux}$$

Where E_{flux} corresponds to: $E_{flux}= E_{elements\ of\ fine\ alloying}+E_{scrap\ high\ in\ Carbon}+E_{scrap\ low\ in\ Carbon}+E_{actif\ carbon}+E_{forge\ carbon}-E_{steel}-E_{process\ residues}$

All emission factors are taken from the 2007 guidelines- Tier 1.

Regarding previous years, a lack of data doesn't make it possible to apply this new approach to the years preceding 2015.

The resulting emissions for the steel production are:

2015 – CO_2 Emissions$_{EAF}$ = 122.80 Gg CO2

2014 – CO_2 Emissions$_{EAF}$ = 102.46 Gg CO2

2013 – CO_2 Emissions$_{EAF}$ = 101.59 Gg CO_2

2012 – CO_2 Emissions$_{EAF}$ = 100.23 Gg CO_2

2011 – CO_2 Emissions$_{EAF}$ = 123.86 Gg CO_2

2010 – CO_2 Emissions$_{EAF}$ = 133.61 Gg CO_2

2009 – CO_2 Emissions$_{EAF}$ = 112.66 Gg CO_2

2008 – CO_2 Emissions$_{EAF}$ = 134.69 Gg CO_2

2007 – CO_2 Emissions$_{EAF}$ = 162.22 Gg CO_2

2006 – CO_2 Emissions$_{EAF}$ = 170.49 Gg CO_2

$$2005 - CO_2\ Emissions_{EAF} = 119.13\ Gg\ CO_2$$

$$2004 - CO_2\ Emissions_{EAF} = 152.45\ Gg\ CO_2$$

For the previous years (1993 to 2003), for which detailed data are not available, a simplified methodology has been applied based on the emission factor determined for the year 2004:

$$CO_2\ Emissions_{EAF} = EF_{EAF} \bullet Steel\ Production$$

It is assumed that the calculated emission factor for the year 2004 is the same for the previous years (1993 to 2003).

PRIMUS® process (PRIMUS)

The PRIMUS process was shut down in 2009. The ETS 2004 guidelines are applied for calculating the emissions in 2009.

$$E_{Primus} = (C_{Raw\ materials} + C_{Electrodes} + C_{Carbon} + C_{Anthracite} - C_{Products})\ x\ 44/12$$

It is assumed that $C_{Products}$ equals zero (Source: ETS declaration).

The activity data are collected from the operator (consumption of electrodes, carbon and anthracite with their respective carbon contents).

The resulting emissions in 2009 are:

$$Emissions_{PRIMUS} = 16.00\ Gg\ CO_2$$

The same methodology is applied for the years 2005 to 2009.

The emissions for the years 2003 and 2004 are estimated based on the relative carbon consumption (Table 4-12) and the average ratio of the CO_2 emissions per carbon consumption for the years 2005-2008.

Table 4-12 – Carbon consumption of the Primus process

Year	Carbon consumption (t)
2003	2 376
2004	6 592
2005	11 781
2006	12 850
2007	13 302
2008	10 683
2009	NA
2010	NO
2011	NO
2012	NO
2013	NO
2014	NO
2015	NO
Source: plant operator	
Note: Facility shut down in 2009	

4.4.1.2.3 Emission factors

For **SP, BF and BOF**, EFs are calculated from the determined CO_2 emissions and the production data in 1990. The EF is kept constant for the subsequent years 1991 to 1997: see Table 4-13.

Table 4-13 – EFs for SP, BF and BOF

Production (1990)	Emissions (1990)	EF
4 804 000 t sinter	380.44 Gg CO_2	EF_{SP} = 79.19 kg CO_2 / t sinter
2 645 200 t iron	200.00 Gg CO_2	EF_{BF} = 75.61 kg CO_2 / t iron
3 506 230 t steel	404.48 Gg CO_2	EF_{BOF} = 115.36 kg CO_2 / t steel

For **EAF**, the EF_{EAF} is calculated from the determined CO_2 emissions and the production data. For the period from 1993 to 2004, the EF is equal to the one determined for the year 2004. For the years 2005 and 2006, EFs are recalculated for each year: see Table 4-14.

Table 4-14 – EFs for EAF

Year	Production t steel	Emissions Gg CO2	EF_{EAF} *(kg CO_2 / t steel)*
2005	2 194 485	119.13	57.86
2006	2 802 049	170.49	60.85
2007	2 845 872	162.22	57.00
2008	2 584 341	134.69	52.12
2009	2 103 281	112.66	53.56
2010	2 633 613	133.61	50.73
2011	2 525 697	123.86	49.04
2012	2 208 000	100.23	45.39
2013	2 089 000	101.59	48.63
2014	2 192 999	102.46	46.72
2015	2 126 283	122.8	57.75

The calculated emission factor for steel production in 2004 (EF_{EAF} = 56.80 kg CO_2 / t steel) and also applied for the previous years (1993 to 2003) is consistent with the calculated emission factors for the subsequent years (2005 to 2015).

For the PRIMUS® process, the implied emission factors EF_{PRIMUS}, for the years 2005-2009, are calculated from the determined CO_2 emissions and the introduced filter dust (Table 4-15).

Table 4-15 – AD, emissions and IEF for Primus

Year	Filter dust (t)	Emissions (Gg CO2)	EF PRIMUS (Mg CO2 / t dust)
2005	29 263	33.79	1.15
2006	38 942	39.30	1.01
2007	46 446	41.27	0.89
2008	35 717	34.61	0.97
2009	16 514	16.00	0.97
2010	NO	NO	NA
2011	NO	NO	NA
2012	NO	NO	NA
2013	NO	NO	NA
2014	NO	NO	NA
2015	NO	NO	NA
Note: Facility shut down in 2009			

4.4.1.3 Uncertainties and time-series consistency

The following input uncertainties are assumed:

- Activity data uncertainty: 5%
- Emission factor uncertainty: 5%

These values are based on 2006 IPCC Guidelines (Vol3, Ch4, Tab4.4, p4.30). Plant-level data is available through ETS.

4.4.1.4 Source-specific QA/QC and verification

Activity and energy data for 1990 have been cross-checked with the activity data available in STATEC's Statistical Yearbook as well as with those provided by the operator directly or through the TÜV Rheinland 1992-1993 study. The iron and steel IPCC Sub-categories 1A2a (fuel combustion) and 2C1 (process emissions) have been cross-checked to avoid double counting.

The calculated emission factor for steel production in 2004 (EF_{EAF} = 56.80 kg CO_2 / t steel) and also applied for the previous years (1993 to 2003) is consistent with the calculated emission factors for the subsequent years (2005 to 2014).

4.4.1.5 Category-specific recalculations including changes made in response to the review process

Starting 2015, EAF associate emissions calculations were improved through the use of more detailed data. For a detailed description see: Methodology, Electric arc furnace steel production (EAF).

4.4.1.6 Category-specific planned improvements including those in response to the review process

There are no planned improvements to IPCC sub-category 2.C.1.

4.4.2 Ferroalloys Production (2.C.2)

There are no dedicated plants for producing ferroalloys in Luxembourg.

4.4.3 Aluminium Production (2.C.3)

Aluminium production in Luxembourg is made out of aluminium scraps. There is, therefore, no primary aluminium production. The production from aluminium scraps is generating only fuel combustion emissions – hence, no process emissions – and is, therefore, reported under IPCC Sub-category *1.A.2.b – Non-Ferrous Metals*.

4.4.4 Magnesium production (2.C.4)

This source category does not exist in Luxembourg.

4.4.5 Lead production (2.C.5)

This source category does not exist in Luxembourg.

4.4.6 Zinc production (2.C.6)

This source category does not exist in Luxembourg.

4.4.7 Other (as specified in table 2(I).A-H) (2.C.7)

This source category does not exist in Luxembourg.

4.5 Non-energy products from fuels and solvent use (2.D)

This section describes the estimation of carbon dioxide emissions resulting from non-energy products like lubricants or waxes. In 2015, this source category was responsible for 5.37% of CO2 emissions from industrial processes – but only 1.34% in 1990 – and for 0.29% of the total CO2 emissions estimated for Luxembourg. It represented 0.26% of the total GHG emissions in CO2e (excluding LULUCF) in 2015 and 0.17% in 1990. Compared to 2014, emissions increased by 3.03% to attain the level of 29.71 Gg CO2 in 2015. Compared to 1990, emissions increased by 34.49%.

4.5.1 Lubricant use (2.D.1)

4.5.1.1 Source category description

The emissions of lubricants, which were previously reported under 1A3b were now moved to industrial process.

No manufacturing of lubricants does occur in Luxembourg. Lubricants are either used in road transportation (motor oil and greases) or in the manufacturing and construction industry (mainly greases). Incineration of lubricants (waste oil) does not occur in Luxembourg. Waste oil is either recycled or exported. In 2015, this source category was responsible for 0.04% of the total CO2 emissions estimated for Luxembourg. It represented 0.04% of the total GHG emissions in CO2e (excluding LULUCF) in 2015 and 0.05% in 1990. Compared to 2014, emissions increased by 4.36% to attain the level of 4.56 Gg CO2 in 2015. Compared to 1990, emissions decreased by 26.49%.

An overview of the lubricant related CO2 emissions, as well as of the amount of associated carbon stored is provided in Table 4-16.

Table 4-16 Emissions from 2.D.1 Lubricant Use

2D1 - Lubricant Use				
Activity data, emissions				
Year	AD	CO_2	Fraction of carbon stored	Carbon stored
	t	*Gg*		*Gg C*
1990	10524.00	6.20	0.8	6.7690368
1991	10696.00	6.31	0.8	6.8796672
1992	10199.00	6.01	0.8	6.5599968
1993	9655.00	5.69	0.8	6.210096
1994	10004.00	5.90	0.8	6.4345728
1995	10223.00	6.03	0.8	6.5754336
1996	10175.00	6.00	0.8	6.54456
1997	9038.00	5.33	0.8	5.8132416
1998	9061.00	5.34	0.8	5.8280352
1999	7648.00	4.51	0.8	4.9191936
2000	7102.00	4.19	0.8	4.5680064
2001	6745.00	3.98	0.8	4.338384
2002	7067.00	4.17	0.8	4.5454944
2003	6645.00	3.92	0.8	4.274064
2004	5040.00	2.97	0.8	3.241728
2005	6153.00	3.63	0.8	3.9576096
2006	4961.00	2.93	0.8	3.1909152
2007	4825.00	2.84	0.8	3.10344
2008	4103.00	2.42	0.8	2.6390496
2009	3416.00	2.01	0.8	2.1971712
2010	3729.00	2.20	0.8	2.3984928
2011	8731.00	5.15	0.8	5.6157792
2012	7572.00	4.46	0.8	4.8703104
2013	7853.00	4.63	0.8	5.0510496
2014	7446.00	4.39	0.8	4.7892672
2015	7736.00	4.56	0.8	4.9757952
Trend 2014-2015	*3.89%*	*3.89%*	*0.00%*	*3.89%*
Trend 1990-2015	*-26.49%*	*-26.49%*	*0.00%*	*-26.49%*

Sources: AD: STATEC ; CO2: Environment Agency

4.5.1.2 Methodology

Generally speaking, lubricant emissions estimations in Luxembourg are based on the Tier 1(Chap5, Tab.5.2, p5.7) methods described in the 2006 IPCC Guidelines for National Greenhouse Gas inventories. Activity data (import/export) for the years 1990 to 2015 were obtained from STATEC.

4.5.1.3 Uncertainties and time-series consistency

The error values which are assumed on the various calculations are as given (IPCC 2006 Guidelines Vol3 Ch5 p. 5.10):

- Activity data uncertainty: 5%
- Emission factor uncertainty: 50%

4.5.1.4 Source-specific QA/QC and verification

The calculations of the data for category 3 are embedded in the overall QA/QC-system of the GHG inventory (see Chapter 1.6) of which important elements include:

- Are the correct values used (check for transcription errors, …)?
- Check of plausibility of input data (time-series, order of magnitude, …)
- Is the data set complete for the whole time series?
- Check of calculations, units ...
- Check of plausibility of results (time-series, order of magnitude, …)
- Correct transformation/transcription into CRF
- Where possible, data is checked with data from other sources, order of magnitude checks, …
- Are all references clearly made?
- Are all assumptions documented?

4.5.1.5 Category-specific recalculations including changes made in response to the review process

The fraction of carbon stored as well as the carbon stored have been added for the years 1990 to 2015.

4.5.1.6 Category-specific planned improvements including those in response to the review process

There are currently no planned improvements in sector 2.D.1.

4.5.2 Paraffin wax use (2.D.2)

4.5.2.1 Source category description

No manufacturing of products from the paraffin wax category occurs in Luxembourg, as such all used products are imported. In 2015, this source category was responsible for 0.01% of the total CO2 emissions estimated for Luxembourg. It represented 0.01% of the total GHG emissions in CO2e (excluding LULUCF) in 2015 and 0.002% in 1990. Compared to 2014, emissions decreased by 9.51% to attain the level of 1.54 Gg CO2 in 2015. Compared to 1990, emissions increased by 630.57%.

An overview of the paraffin wax related CO2 emissions is provided in table Table 4-17.

Table 4-17 Emissions from 2.D.2 Paraffin Wax Use

2D2 - Paraffin Wax Use		
Activity data, emissions		
Year	AD	CO_2
	t	*Gg*
1990	357.16	0.21
1991	361.99	0.21
1992	366.82	0.22
1993	371.84	0.22
1994	376.95	0.22
1995	382.43	0.23
1996	387.36	0.23
1997	392.19	0.23
1998	397.11	0.23
1999	371.51	0.22
2000	413.31	0.24
2001	396.54	0.23
2002	397.54	0.23
2003	469.48	0.28
2004	441.56	0.26
2005	439.36	0.26
2006	295.88	0.17
2007	283.61	0.17
2008	424.01	0.25
2009	213.16	0.13
2010	2177.23	1.28
2011	1268.85	0.75
2012	1135.95	0.67
2013	4526.83	2.67
2014	2883.55	1.70
2015	2609.31	1.54
Trend 2014-2015	*-9.51%*	*-9.51%*
Trend 1990-2015	*630.57%*	*630.57%*

Sources: AD: STATEC ; CO2: Environment Agency

4.5.2.2 Methodology

The emissions of paraffin wax in Luxembourg were assessed in 2014 in order to assure compliance with the 2006 IPCC reporting guidelines.

Generally speaking, paraffin wax emissions estimations in Luxembourg are based on the Tier 1 (Chap5, Tab.5.3., p5.11) methods described in the 2006 IPCC Guidelines for National Greenhouse

Gas inventories. Activity data (import/export) for the years 1999 to 2014 were obtained from STATEC. For the years 1990 to 1998, the data was extrapolated based population data and on the average import/export data for the years 1999-2005.

4.5.2.3 Uncertainties and time-series consistency

The error values which are assumed on the various calculations are as given (IPCC 2006 Guidelines Vol.3 Ch.5 p. 5.13):

- Activity data uncertainty 5%
- Emission factor uncertainty 100%

4.5.2.4 Source-specific QA/QC and verification

The calculations of the data for category 3 are embedded in the overall QA/QC-system of the GHG inventory (see Chapter 1.6) of which important elements include:

- Are the correct values used (check for transcription errors, …)?
- Check of plausibility of input data (time-series, order of magnitude, …)
- Is the data set complete for the whole time series?
- Check of calculations, units ...
- Check of plausibility of results (time-series, order of magnitude, …)
- Correct transformation/transcription into CRF
- Where possible, data is checked with data from other sources, order of magnitude checks, …
- Are all references clearly made?
- Are all assumptions documented?

4.5.2.5 Category-specific recalculations including changes made in response to the review process

No revisions and recalculations have been done since the last submission.

4.5.2.6 Category-specific planned improvements including those in response to the review process

Obtaining country specific data for the years 1990 to 1998, alternatively improvements to the estimations of the activity data and emissions concerning those years will be performed.

4.5.3 Other (2.D.3)

4.5.3.1 Solvent use (2.D.3.1)

4.5.3.1.1 Sector Overview

Solvents are chemical compounds, which are used to dissolve substances as paint, glues, ink, rubber, plastic, pesticides or for cleaning purposes (degreasing). Solvents used in products such as coatings, inks, and consumer products generally emit substances classified as VOCs (Volatile Organic Compounds). Because solvents consist mainly of NMVOC, solvent use is a major source for anthropogenic NMVOC emissions in Luxembourg. Once released into the atmosphere NMVOCs react with reactive molecules (mainly HO-radicals) or high energetic light to finally form CO_2.

For more details on categories where emissions are not occurring and categories that are not estimated or included elsewhere, see section Table 4-19.

4.5.3.1.2 Emission Trends

In 2015, this source category was responsible for 0.13% of the total CO2 emissions estimated for Luxembourg. Furthermore, in 2015, 0.12% of total GHG emissions (excluding LULUCF) in Luxembourg originated from *Solvent and Other Product Use*, compared to 0.12% in 1990. Compared to 2014, GHG emissions from *Solvent and Other Product Use* increased by 16,6%. Compared to 1990, emissions decreased by 10,8%.

Figure 4-7and Table 4-18 present the trend in total greenhouse gas emissions by subcategories.

Figure 4-7 - Emissions and trend from 1990 – 2015 by Sub-Categories of 2.D.3.1 - Solvent and Other Product Use.

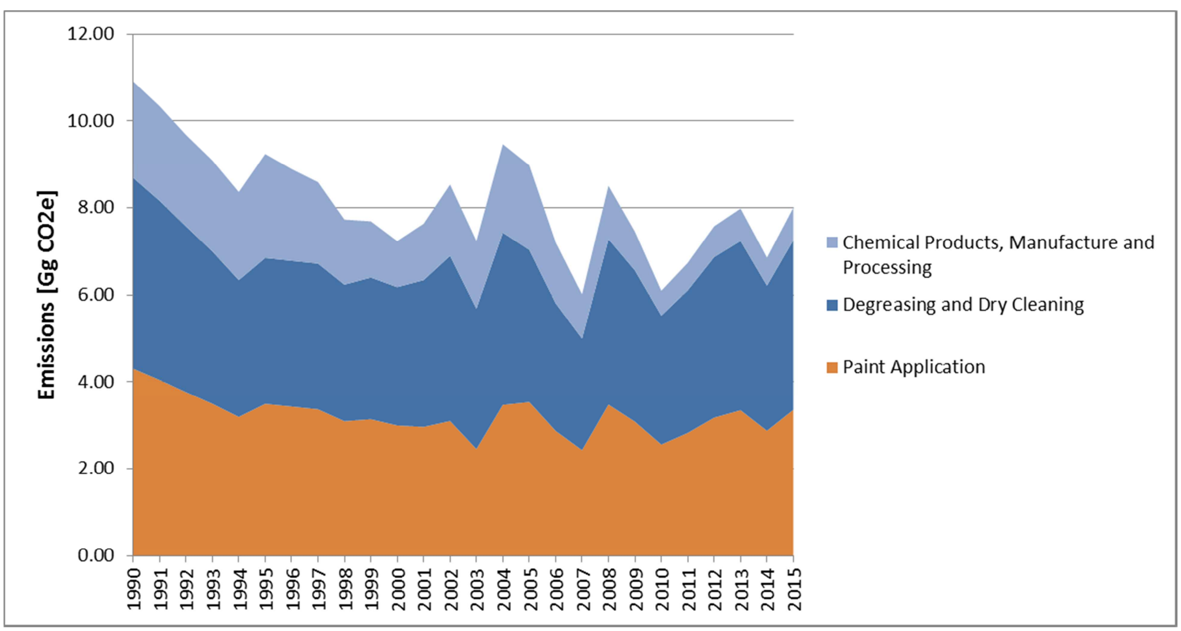


Table 4-18 - Emissions and trend from 1990 – 2015 by Sub-Categories of 2.D.3.1 ***- Solvent and Other Product Use.***

GHG	2.D.3.1 Other – Solvent use	Paint Application	Degreasing and Dry Cleaning	Chemical Products, Manufacture and Processing	Other
	Gg of CO_2 eq				
1990	15.41	4.31	4.38	2.22	4.50
1991	14.80	4.05	4.12	2.18	4.46
1992	14.02	3.76	3.81	2.11	4.34
1993	13.29	3.50	3.50	2.09	4.19
1994	12.33	3.19	3.15	2.02	3.96
1995	13.68	3.49	3.36	2.39	4.45
1996	13.41	3.43	3.35	2.11	4.51
1997	13.17	3.37	3.35	1.87	4.58
1998	12.07	3.09	3.14	1.49	4.34
1999	12.24	3.14	3.26	1.29	4.55
2000	11.72	3.00	3.18	1.05	4.48
2001	12.25	2.96	3.38	1.29	4.61
2002	13.56	3.10	3.80	1.64	5.03
2003	11.40	2.45	3.24	1.55	4.16
2004	14.99	3.47	3.96	2.04	5.53
2005	14.30	3.54	3.50	1.95	5.32
2006	11.64	2.87	2.94	1.39	4.44
2007	9.87	2.43	2.57	1.02	3.86
2008	14.17	3.48	3.80	1.23	5.66
2009	12.60	3.09	3.48	0.89	5.15
2010	10.47	2.56	2.97	0.57	4.38
2011	11.57	2.82	3.28	0.63	4.83
2012	13.01	3.18	3.69	0.71	5.44
2013	13.71	3.35	3.89	0.74	5.73
2014	11.78	2.88	3.34	0.64	4.92
2015	13.74	3.36	3.90	0.75	5.74
Trend 2014–2015	17%	17%	17%	17%	17%
Trend 1990–2015	-11%	-22%	-11%	-66%	28%
Share in CRF 3 in 1990		28%	28%	14%	29%
Share in CRF 3 in 2015		24%	28%	5%	42%

Greenhouse gas emissions in this sector dencreased by 11% between 1990 and 2015, due to the positive impact of the enforced laws and regulations in Luxembourg:

- Solvent Ordinance: for limitation of emission of volatile organic compounds due to the use of organic solvents in certain paints and varnishes and vehicle refinishing products in order to combat acidification and ground-level ozone[109];
- Ordinance for paint finishing system (surface technology systems): for limitation of emission of volatile organic compounds due to the use of organic solvents by activities such as surface coating, painting or varnishing of different materials and products along the entire chain in the painting process in order to combat acidification and ground-level ozone[110]
- Ordinance for industrial facilities and installations applying chlorinated hydrocarbon: for limitation of emission of chlorinated organic solvents from industrial facilities and installations applying chlorinated hydrocarbon;
- Convention on Long-range Transboundary Air Pollution (LRTAP)[111], extended by eight protocols from which the following have relevance:
  - The 1988 Protocol concerning the Control of Nitrogen Oxides or their Transboundary Fluxes;[112]
  - The 1991 Protocol concerning the Control of Emissions of Volatile Organic Compounds or their Transboundary Fluxes;[113]
  - The 1998 Protocol on Persistent Organic Pollutants (POPs);[114]
  - The 1999 Protocol to Abate Acidification, Eutrophication and Ground-level Ozone; 21 Parties.[115]
- Ordinance for volatile organic compounds (VOC) due to the use of organic solvents in certain activities and installations;[116]

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109 Règlement grand-ducal du 7 avril 2011 remplaçant l'annexe III du règlement grand-ducal modifié du 25 janvier 2006 relatif à la réduction des émissions de composés organiques volatils dues à l'utilisation de solvants organiques dans certains vernis et peintures et dans les produits de retouche de véhicules. (implementation of European Council Directive 2004/42/CE and European Council Directive 2010/79/EC).

110 Règlement grand-ducal du 20 décembre 1995 relatif à certaines modalités d'application et à la sanction du règlement CE N° 3093/94 du Conseil du 15 décembre 1994 relatif à des substances qui appauvrissent la couche d'ozone.

111 Loi du 18 juin 1981 portant approbation de la Convention sur la pollution atmosphérique transfrontière à longue distance, en date à Genève, du 13 novembre 1979. (Convention entered into force 16 March 1983; ratified by Luxembourg 15 July 1982)

112 Loi du 31 juillet 1990 portant approbation du Protocole à la Convention sur la pollution atmosphérique transfrontière à longue distance de 1979, relatif à la lutte contre les émissions d'oxydes d'azote ou leurs flux transfrontières, fait à Sofia, le 31 octobre 1988. (Protocol entered into force 14 February 1991; ratified by Luxembourg 4 October 1990)

113 Loi du 29 juillet 1993 portant approbation du Protocole à la Convention sur la pollution atmosphérique transfrontière à longue distance, de 1979, relatif à la lutte contre les émissions de composés organiques volatils ou de leurs flux transfrontières, fait à Genève, le 18 novembre 1991. (Protocol entered into force 29 September 1997; ratified by Luxembourg 11.11.1993)

114 Loi du 24 décembre 1999 portant approbation du Protocole à la Convention sur la pollution atmosphérique transfrontière à longue distance, de 1979, relatif aux polluants organiques persistants, fait à Aarhus (Danemark), le 24 juin 1998. (Protocol entered into force on 23 October 2003; ratified by Luxembourg 01.05.2000)

115 Loi du 14 juin 2001 portant approbation du Protocole à la Convention de 1979 sur la pollution atmosphérique transfrontière à longue distance, relatif à la réduction de l'acidification, de l'eutrophisation et de l'ozone troposphérique, fait à Göteborg, le 30 novembre 1999. (Protocol entered into force on 17 May 2005; ratified by Luxembourg 07.08.2001)

- European Council Directive 1999/13/EC of March 1999 on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations;
- European Council Directive 2004/42/CE of the European Parliament and of the Council of 21 April 2004 on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain paints and varnishes and vehicle refinishing products and amending Directive 1999/13/EC;
- Regulation on the limitation of emission during the use of solvents containing lightly volatile halogenated hydrocarbons in industrial facilities and installations.[117]

4.5.3.1.3 Completeness

Table 4-19 gives an overview of the IPCC categories included in this chapter and presents the transformation matrix from SNAP categories. It also provides information on the status of emission estimates of all subcategories. A "✓" indicates that emissions from this sub-category have been estimated.

Table 4-19 - Overview of subcategories of IPCC Category 2.D.3.1 - Solvents and Other Product Use: correlation with SNAP codes and status of estimation.

IPCC Category		SNAP		CO_2	N_2O
3.A	Paint application	0601	Paint application	✓	NA
3.B	Degreasing and Dry Cleaning	0602	Degreasing, dry cleaning and electronics	✓	NA
3.C	Chemical Products, Manufacture and Processing	0603	Chemical products manufacturing and processing	✓	NA
3.D	Other	0604	Other use of solvents and related activities	✓	NA

4.5.3.1.4 CO_2 Emissions from Solvent and Other Product Use

4.5.3.1.4.1 Methodology Overview

CO_2 emissions from solvent use were calculated from NMVOC emissions of this sector. As a first step the quantity of solvents used and the solvent emissions were calculated. To determine the quantity of solvents used, in Luxembourg, in the various applications, a bottom up and a top down approach were combined. Figure 4-8 to Figure 4-10 present an overview of the methodology.

The top down approach provides total quantities of solvents used in Luxembourg. The share of solvents used for the different applications and the solvent emission factors have been calculated on the basis of the bottom up approach. It was based on the economic structure in Luxembourg,

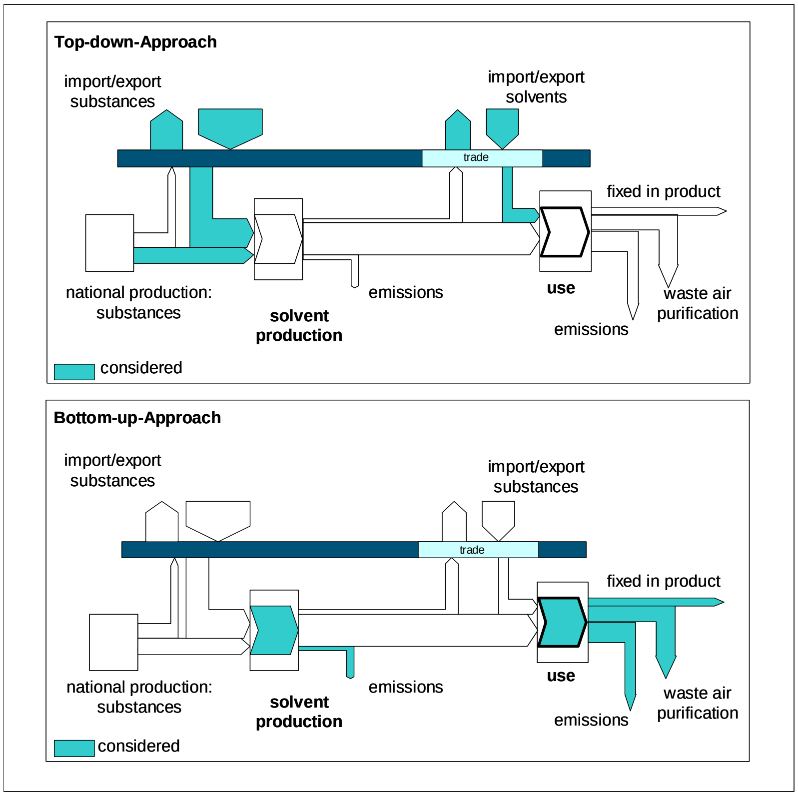
116 *Règlement grand-ducal du 3 décembre 2010 modifiant le règlement grand-ducal modifié du 4 juin 2001 portant - application de la directive 1999/13/CE du Conseil du 11 mars 1999 relative à la réduction des émissions de composés organiques volatils dues à l'utilisation de solvants organiques dans certaines activités et installations; - modification du règlement grand-ducal modifié du 16 juillet 1999 portant nomenclature et classification des établissements classes;.*

117 Règlement grand-ducal du 12 juillet 1995, relatif aux générateurs d'aérosols.

applying solvent use and emission factors from the Austrian survey by linking the results of bottom up and top down approach, quantities of solvents annually used and solvent emissions for the different applications were obtained.

This model has been developed for Austria[118] (WINDSPERGER *et al.* 2002a, 2004) and was in the meantime applied for different European countries within the network "non-energy use of fossils and CO_2 emissions" (WINDSPERGER & STEINLECHNER, 2006). The application for Luxembourg is suitable as both countries show similar situation regarding economic and technical structure, and moreover as members of the EU similar legal framework conditions.

Figure 4-8 - Top-down-Approach compared to Bottom-up-Approach.



118

Figure 4-9 - Overview of the methodology for solvent emissions.

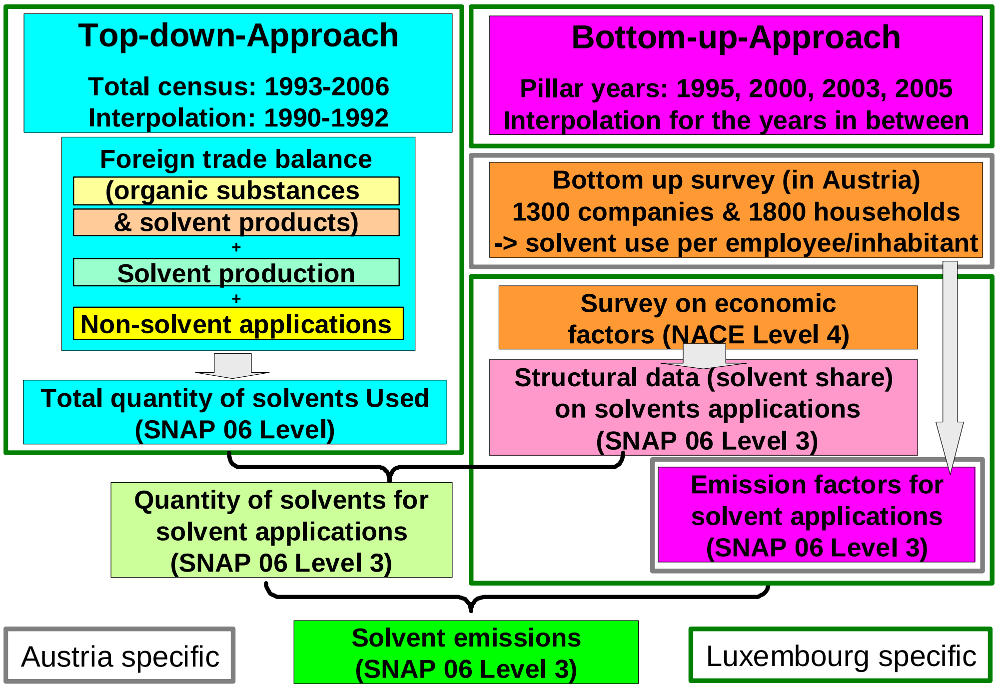


Figure 4-10 - Data of Top-down-Approach and Bottom-up-Approach for 2013.

Top-down: CRF Sector 3			
Imp/Exp Solvent products	2		
Inland Solvent production	10	Solvents in applications: 5	Solvent Activity: 7
Imp/Exp Organic Substances	14	Substances used as solvents: -5	
Non-solvent applications	-19		

Bottom-up: CRF Sector 3A-3D	SNAP Level 3		Solvent Share CRF 3	Solvent Share CRF 3A-D	Solvent Share SNAP Lev 3	Solvent Emission Factor CRF 3	Solvent Emission Factor CRF 3A-D	Solvent Emission Factor SNAP Lev 3	Combination Top-down to Bottom-up: Solvent Activity CRF 3	Solvent Activity CRF 3A-D	Solvent Activity SNAP Lev 3	Solvent Emissions CRF 3	Solvent Emissions CRF 3A-D	Solvent Emissions SNAP Lev 3
3 A, Paint application	060101	Manufacture of automobiles	100%	26%	0.3%	68%	67%	64%	7.4	1.9	0.0	5.0	1.3	0.0
	060102	Car repairing			1.0%			86%			0.1			0.1
	060103	Construction and buildings			6.6%			89%			0.5			0.4
	060104	Domestic use			1.3%			89%			0.1			0.1
	060105	Coil coating			2.4%			52%			0.2			0.1
	060107	Wood coating			2.3%			90%			0.2			0.2
	060108	Other industrial paint application			11.9%			50%			0.9			0.4
3 B, Degreasing and Dry Cleaning	060201	Metal degreasing		31%	13.6%		51%	29%		2.3	1.0		1.2	0.3
	060202	Dry cleaning			0.3%			84%			0.0			0.0
	060203	Electronic components manufact.			0.0%			82%			0.0			0.0
	060204	Other industrial cleaning			16.7%			68%			1.2			0.8
3 C, Chemical Products, Manufacture and Processing	060305	Rubber processing		10%	6.3%		83%	93%		0.7	0.5		0.6	0.4
	060306	Pharmaceutical products manufact.			0.7%			26%			0.1			0.0
	060307	Paints manufacturing			0.5%			100%			0.0			0.0
	060308	Inks manufacturing			0.7%			100%			0.0			0.0
	060309	Glues manufacturing			0.0%			100%			0.0			0.0
	060310	Asphalt blowing			0.7%			1%			0.0			0.0
	060311	Adhesive, films & photographs			0.0%			94%			0.0			0.0
	060312	Textile finishing			0.0%			90%			0.0			0.0
	060314	Other manufacturing			0.9%			100%			0.1			0.1
3 D, Other	060403	Printing industry		34%	9.7%		79%	65%		2.5	0.7		2.0	0.5
	060404	Fat and oil extraction			0.3%			20%			0.0			0.0
	060405	Application of glues and adhesives			0.0%			63%			0.0			0.0
	060406	Preservation of wood			0.1%			99%			0.0			0.0
	060407	Treatment & conservation of vehicles			0.3%			85%			0.0			0.0
	060408	Domestic solvent use (other)			17.3%			84%			1.3			1.1
	060411	Domestic use of pharmac. products			4.0%			94%			0.3			0.3
	060412	Other (preservation of seeds,...)			2.1%			78%			0.2			0.1

A study compiled for Austria (WINDSPERGER *et al.* 2002a) showed huge overestimation of NMVOC emissions when emission estimates are based on a top down approach only because a large amount of substances is used for "non-solvent-applications". "Non-solvent applications" are applications where substances usually are used as feed stock in chemical, pharmaceutical or petrochemical industry (*e.g.* production of MTBE/ETBE, formaldehyde, polyester, biodiesel, pharmaceuticals *etc.*)

and where therefore no emissions from "solvent use" arise. However, there might be emissions from the use of the produced products, such as MTBE/ETBE which is used as fuel additive and finally combusted; these emissions are considered in the transport sector.

Additionally, the comparison of the top-down and the bottom-up approaches helped to identify several quantitatively important applications like windscreens wiper fluids, antifreeze, moonlighting, hospitals, de-icing agents of aeroplanes, tourism, which were not considered in the top-down approach.

4.5.3.1.4.2 Top down Approach

The top-down approach is based on:

1. import-export statistics on solvent substances and solvent containing products (foreign trade balance) (STATEC);
2. production statistics on solvents in Luxembourg;
3. a survey on non-solvent-applications in companies in Austria (Windsperger *et al.* 2004a);
4. survey on the solvent content in products and preparations at producers and retailers in Austria (Windsperger *et al.* 2002a).

ad (1) and (2): Total quantity of solvents used in Luxembourg were obtained from import-export statistics and production statistics provided by STATEC.

Nearly a full top down investigation of substances of the import-export statistics from 1993 to 2008 was carried out (data 1990 – 1992 were interpolated). One problem is that the methodology of the import-export statistics changed over the years. In case of severe deviations between some years smoothing the time series with the mean values was used.

In Luxembourg, there are only few facilities producing solvents. The production of solvents considerably decreased, especially in the last years.

ad (3): In a study on the comparison of top down and bottom up approach in Austria (WINDSPERGER *et al.* 2002a), the amount of solvents used in "non-solvent-applications" was identified. The most important companies in Austria were identified and asked to report the quantities of solvents they used over the considered time period in „non-solvent-applications". In combination with import-export statistic for these solvent substances the percentages of „non-solvent-applications" were calculated.

For Luxembourg, these percentages of "non-solvent-applications" were adapted to the country's specific situation according to information from companies in Luxembourg.

ad (4): Relevant producers and retailers provided data on solvent content in products and preparations in Austria. These data were also adapted to Luxembourg due to the country specific situation.

4.5.3.1.4.3 Bottom up Approach

In a first step, an extensive survey on the use of solvents in the year 2000 was carried out in 1 300 Austrian companies (WINDSPERGER *et al.* 2002b). In this extensive survey data about the solvent content of paints, cleaning agents *etc.* and on solvents used (both substances and substance categories) like acetone or alcohols were collected.

Furthermore, information was gathered on:

- type of application of the solvents: "final application", "cleaner" and "product preparation" as well as
- actual type of waste gas treatment: "open application", "waste gas collection" and "waste gas treatment".

For every category of application and waste gas treatment an emission factor was estimated to calculate solvent emissions in the year 2000 (see Table 4-20).

The survey in 1 300 Austrian companies in the year 2000 was carried out at all industrial branches with solvent applications at NACE-level-4. Within these NACE-levels data on solvent use distinguished in substance categories was collected from the companies and a factor of "solvent use per employee" was calculated. For the calculation of the total amounts within the SNAP-digit (level 3) the number of employees in the respective NACE-levels in 2000 was used (WINDSPERGER *et al.* 2002b). In accordance with statistics in other European countries the structural business statistics (number of employees (NACE Rev.1.1)) were taken from EUROSTAT 2008 [119].

Table 4-20 - Emission factors for NMVOC emissions from Solvent Use.

Category	Factor
final application	1.00
cleaner	0.85
product preparation	0.05
open application	1.00
waste gas collection	0.50
waste gas treatment	0.20

In a second step a survey in 1 800 households was made (WINDSPERGER *et al.* 2002a) for estimating the domestic solvent use (37 categories in 5 main groups: cosmetic, do-it-yourself, household cleaning, car, fauna and flora). Also, solvent use in the context of moonlighting besides commercial work and do-it-yourself was calculated.

The comparison of top down and bottom up approach helped to identify several additional applications that make an important contribution to the total amount of solvents used. Thus in a

119 http://epp.eurostat.ec.europa.eu

third step the quantities of solvents used in these applications such as windscreens wiper fluids, antifreeze, hospitals, de-icing agents of aeroplanes, tourism were estimated in surveys.

The outcome of these three steps was the total amount of solvents used for each application in the year 2000 (at SNAP level 3) in Austria (WINDSPERGER *et al.* 2002a).

To adapt the values for Luxembourg coefficients of the solvent consumption per employee (respective inhabitant) were used and applied to the employees of the industry sectors in Luxembourg (resp. Inhabitants). The outcome was the total amount of solvents for every application in the year 2000 in Luxembourg.

To achieve a time series, the development of the economic and technical situation in relation to the year 2000 was considered. It was distinguished between "general aspects" and "specific aspects" (see

Table 4-22, Table 4-23 and Table 4-23). The information about these defined aspects were collected for two pillar years (1990 and 1995) and were taken from several studies (SCHMIDT *et al.* 1998, BARNERT 1998) and expert judgements from associations of industries (chemical industry, printing industry, paper industry) and other stakeholders. On the basis of this information calculation factors were estimated. With these factors and the data for solvent use and emission of 2000 data for the two pillar years was estimated. For the years in between, data was linearly interpolated. Since 2000, no new survey has been conducted so that the data remain constant since then.

For the pillar year 2005 and 2010 country specific data are used to update the bottom-up approach:

- update by of emission factors, type of waste gas treatment and solvent content by using information from solvents balances reported under the Solvent Ordinance.
- update of plant specific information from associations of industries and statistical data for "general aspects" and "specific aspects" .

Table 4-21 - General aspects and their development.

General aspects	1990	1995	2000	2005
efficiency factor solvent cleaning	150%	130%	100%	100%
efficiency factor application	110%	105%	100%	100%
solvent content of water-based paints	12%	10%	8%	8%
solvent content of solvent-based paints	58%	55%	55%	55%
efficiency of waste gas purification	75%	78%	80%	80%

Table 4-22 - Specific aspects and their development: distribution of the used paints (water based-paints – solvent-based paints) and part of waste gas purification (application – purification).

SNAP category	description	year	Distribution of used paints		Part of waste gas treatment	
			Solvent based paints	Water based paints	application	Purification
060101	manufacture of automobiles	2005	73%	27%	10%	0%
		2000	73%	27%	10%	0%
		1995	80%	20%	8%	0%
		1990	90%	10%	5%	0%
060102	car repairing	2005	51%	49%	62%	1%
		2000	51%	49%	62%	1%
		1995	55%	45%	60%	0%
		1990	75%	25%	10%	0%
060107	wood coating	2005	46%	54%	46%	3%
		2000	46%	54%	46%	3%
		1995	60%	40%	45%	2%
		1990	85%	15%	10%	0%
060108	Other industrial paint application	2005	97%	3%	90%	46%
		2000	97%	3%	90%	46%
		1995	99%	1%	87%	45%
		1990	100%	0%	26%	20%
060201	Metal degreasing	2005	92%	8%	75%	0%
		2000	92%	8%	75%	0%
		1995	95%	5%	65%	0%
		1990	100%	0%	10%	0%
060403	Printing industry	2005			44%	17%
		2000			44%	17%
		1995			29%	10%
		1990			10%	5%
060405	Application of glues and adhesives	2005			58%	0%
		2000			58%	0%
		1995			53%	0%
		1990			15%	0%
060103	Paint application : construction and buildings	2005	91%	9%	19%	4%
		2000	91%	9%	19%	4%
		1995	93%	7%	15%	2%
		1990	100%	0%	5%	0%
060105	Paint application : coil coating	2005	100%	0%	63%	0%
		2000	100%	0%	63%	0%
		1995	100%	0%	60%	0%
		1990	100%	0%	25%	0%
060406	Preservation of wood	2005	83%	17%	0%	0%
		2000	83%	17%	0%	0%
		1995	85%	15%	0%	0%
		1990	95%	5%	0%	0%
060412	Other (preservation of seeds,…)	2005	100%	0%	90%	0%
		2000	100%	0%	90%	0%
		1995	100%	0%	80%	0%
		1990	100%	0%	10%	0%

Table 4-23 - Specific aspects and their development: changes in the number of employees compared to the year 2000

SNAP	Description	Changes in the number of employees compared to the year 2000				
		1990	1995	2000	2003	2005
0601	Paint application					
060101	manufacture of automobiles	106%	106%	100%	134%	163%
060102	car repairing	93%	93%	100%	120%	125%
060103	construction and buildings	93%	93%	100%	120%	128%
060104	domestic use			separate analysis		
060105	coil coating	106%	106%	100%	32%	38%
060107	wood coating	93%	93%	100%	117%	126%
060108	industrial paint application	93%	93%	100%	100%	110%
0602	Degreasing, dry cleaning and electronics					
060201	Metal degreasing	117%	117%	100%	100%	88%
060202	Dry cleaning	94%	94%	100%	103%	106%
060203	Electronic components manufacturing	3%	3%	100%	96%	165%
060204	Other industrial cleaning	76%	76%	100%	134%	143%
0603	Chemical products manufacturing and processing					
060305	Rubber processing	190%	190%	100%	199%	198%
060306	Pharmaceutical products manufacturing	88%	88%	100%	194%	134%
060307	Paints manufacturing	133%	133%	100%	111%	111%
060308	Inks manufacturing	89%	89%	100%	94%	93%
060309	Glues manufacturing	NO	NO	NO	NO	NO
060310	Asphalt blowing	218%	218%	100%	103%	104%
060311	Adhesive, magnetic tapes, films and photographs	84%	84%	100%	70%	70%
060312	Textile finishing	119%	119%	100%	6%	7%
060314	Other	88%	88%	100%	87%	132%
0604	Other use of solvents and related activities					
060403	Printing industry	90%	90%	100%	111%	103%
060404	Fat, edible and non edible oil extraction	0%	0%	100%	155%	177%
060405	Application of glues and adhesives	NO	NO	NO	NO	NO
060406	Preservation of wood	91%	91%	100%	245%	125%
060407	Under seal treatment and conservation of vehicles	71%	71%	100%	102%	102%
060408	Domestic solvent use (other than paint application			analysed separately		
060411	Domestic use of pharmaceutical products (k)					
060412	Other (preservation of seeds,…)	32%	32%	100%	48%	24%

Because of unavailability of data of employees in 1990 in the European database, the number of employees was taken out from 1995.

4.5.3.1.4.4 Combination Top-down – Bottom-up approach and updating

To verify and adjust the data, the solvents given in the top down approach and the results of the bottom up approach were differentiated in the pillar years (1995, 2000, 2003, 2005) (see Table 4-24). The differences between the quantities of solvents from the top down approach and bottom up approach respectively are lower than 10%. Table 4-25 shows the range of the differences in the considered pillar years broken down to the 15 substance categories.

Table 4-24 - Differences between the results of the bottom up and the top down approach for Luxembourg.

Year	Differences [t/a]
2005	-760
2003	0
2000	54
1995	-549

As the data of the top down approach were obtained from national statistics, they are assumed to be more reliable than the data of the bottom up approach. That's why the annual quantities of solvents used were taken from the top down approach while the share of the solvents for the different applications (on SNAP level 3) and the solvent emission factors have been calculated on the basis of the bottom up approach. The following tables (Table 4-26, Table 4-26 and Figure 4-11) present activity data and NMVOC emissions.

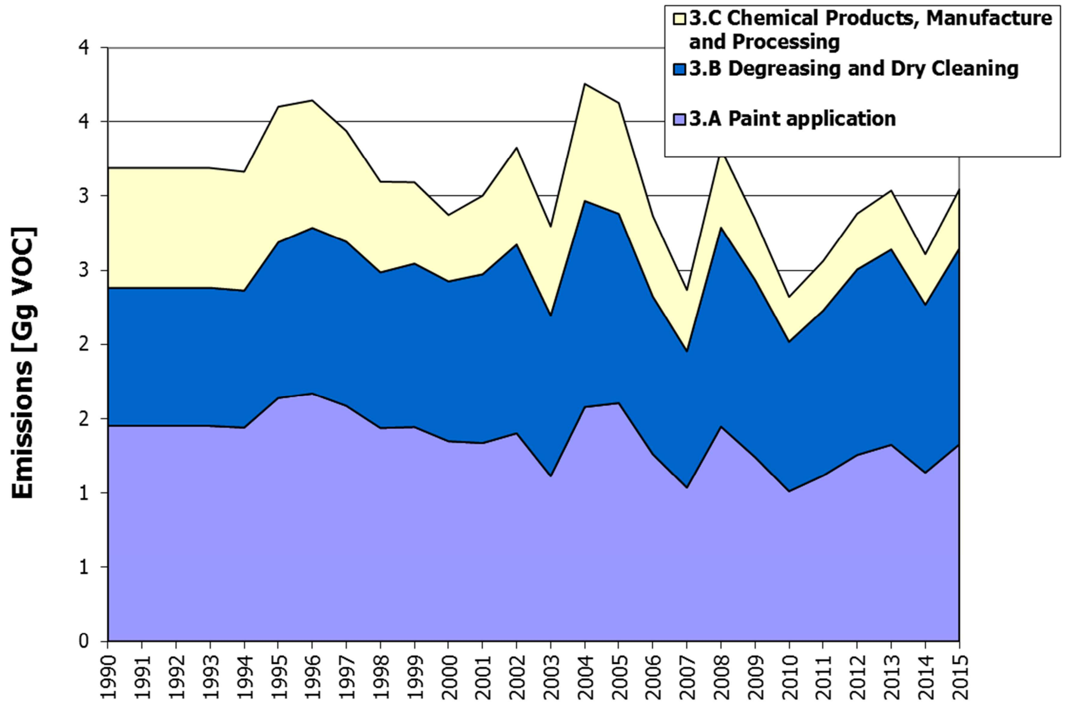
Table 4-25 - Activity data of Category 2.D.3.1 Solvent and other product use [Mg] 1990-2015

	Solvents (Gg)									
	2D3	2D3a	2D3b	2D3c	2D3d	2D3e	2D3f	2D3g	2D3h	2D3i
	TOTAL	Dometics solvent use including fungicides	Road paving with asphalt	Asphalt roofing	Coating applications	Degreasing	Dry cleaning	Chemical products	Printing	Other solvent use (please specify in the IR)
1990	7.124	1.309	IE	IE	1.863	1.890	0.022	1.062	0.774	0.204
1991	7.124	1.309	IE	IE	1.863	1.890	0.022	1.062	0.774	0.204
1992	7.124	1.309	IE	IE	1.863	1.890	0.022	1.062	0.774	0.204
1993	7.124	1.309	IE	IE	1.863	1.890	0.022	1.062	0.774	0.204
1994	7.068	1.299	IE	IE	1.848	1.876	0.022	1.053	0.768	0.202
1995	8.045	1.478	IE	IE	2.103	2.135	0.025	1.199	0.874	0.230
1996	8.356	1.588	IE	IE	2.195	2.266	0.027	1.120	0.903	0.255
1997	8.102	1.591	IE	IE	2.139	2.245	0.026	0.965	0.871	0.263
1998	7.503	1.521	IE	IE	1.991	2.123	0.025	0.782	0.803	0.258
1999	7.711	1.611	IE	IE	2.056	2.227	0.026	0.689	0.820	0.280
2000	7.377	1.588	IE	IE	1.977	2.175	0.026	0.549	0.781	0.283
2001	7.618	1.635	IE	IE	1.940	2.280	0.026	0.647	0.814	0.276
2002	8.336	1.784	IE	IE	2.012	2.533	0.028	0.796	0.900	0.284
2003	6.922	1.477	IE	IE	1.578	2.136	0.023	0.734	0.754	0.221
2004	9.034	2.004	IE	IE	2.289	2.515	0.031	0.950	0.964	0.281
2005	8.553	1.970	IE	IE	2.384	2.124	0.030	0.892	0.894	0.258
2006	6.934	1.642	IE	IE	1.857	1.780	0.025	0.664	0.693	0.274
2007	5.856	1.425	IE	IE	1.504	1.552	0.022	0.510	0.559	0.285
2008	8.371	2.091	IE	IE	2.059	2.288	0.031	0.656	0.761	0.485
2009	7.417	1.901	IE	IE	1.743	2.089	0.028	0.517	0.641	0.498
2010	6.139	1.613	IE	IE	1.375	1.780	0.024	0.375	0.503	0.468
2011	6.779	1.781	IE	IE	1.519	1.966	0.026	0.414	0.556	0.517
2012	7.624	2.003	IE	IE	1.708	2.211	0.029	0.466	0.625	0.582
2013	8.034	2.111	IE	IE	1.800	2.330	0.031	0.491	0.658	0.613
2014	6.901	1.813	IE	IE	1.546	2.001	0.027	0.422	0.566	0.527
2015	8.054	2.116	IE	IE	1.804	2.336	0.031	0.492	0.660	0.615

Table 4-26 - Implied NMVOC emission factors for Solvent Use 1990–2015

NMVOC implied emission factor (g NMVOC/g solvents)										
	2D3	2D3a	2D3b	2D3c	2D3d	2D3e	2D3f	2D3g	2D3h	2D3i
	TOTAL	Dometics solvent use including fungicides	Road paving with asphalt	Asphalt roofing	Coating applications	Degreasing	Dry cleaning	Chemical products	Printing	Other solvent use (please specify in the IR)
1990	0.75	0.86	IE	IE	0.78	0.48	0.88	0.76	0.69	0.77
1991	0.75	0.86	IE	IE	0.78	0.48	0.88	0.76	0.69	0.77
1992	0.75	0.86	IE	IE	0.78	0.48	0.88	0.76	0.69	0.77
1993	0.75	0.86	IE	IE	0.78	0.48	0.88	0.76	0.69	0.77
1994	0.75	0.86	IE	IE	0.78	0.48	0.88	0.76	0.69	0.77
1995	0.75	0.86	IE	IE	0.78	0.48	0.88	0.76	0.69	0.77
1996	0.74	0.86	IE	IE	0.76	0.48	0.87	0.76	0.68	0.75
1997	0.73	0.86	IE	IE	0.74	0.48	0.87	0.77	0.68	0.72
1998	0.72	0.86	IE	IE	0.72	0.48	0.86	0.78	0.67	0.69
1999	0.72	0.86	IE	IE	0.70	0.48	0.86	0.79	0.66	0.67
2000	0.71	0.86	IE	IE	0.68	0.48	0.85	0.82	0.66	0.64
2001	0.72	0.86	IE	IE	0.69	0.49	0.85	0.82	0.66	0.67
2002	0.72	0.86	IE	IE	0.70	0.49	0.85	0.82	0.65	0.69
2003	0.73	0.86	IE	IE	0.71	0.50	0.84	0.82	0.65	0.71
2004	0.73	0.86	IE	IE	0.69	0.54	0.84	0.83	0.65	0.73
2005	0.74	0.86	IE	IE	0.67	0.59	0.84	0.83	0.65	0.74
2006	0.73	0.86	IE	IE	0.68	0.58	0.84	0.82	0.61	0.70
2007	0.71	0.86	IE	IE	0.69	0.58	0.84	0.81	0.57	0.65
2008	0.70	0.86	IE	IE	0.70	0.57	0.84	0.80	0.52	0.60
2009	0.66	0.86	IE	IE	0.71	0.56	0.84	0.79	0.41	0.46
2010	0.65	0.86	IE	IE	0.74	0.55	0.84	0.81	0.35	0.38
2011	0.65	0.86	IE	IE	0.74	0.55	0.84	0.81	0.35	0.38
2012	0.65	0.86	IE	IE	0.74	0.55	0.84	0.81	0.35	0.38
2013	0.65	0.86	IE	IE	0.74	0.55	0.84	0.81	0.35	0.38
2014	0.65	0.86	IE	IE	0.74	0.55	0.84	0.81	0.35	0.38
2015	0.65	0.86	IE	IE	0.74	0.55	0.84	0.81	0.35	0.38

Figure 4-11 - NMVOC emissions and trend from 1990–2015 by subcategories of Category 2.D.3.1 - Solvent and Other Product Use



4.5.3.1.4.5 Calculation of CO_2 emissions from Solvent Emissions

The basis for the calculation of the carbon dioxide emissions were the quantities of solvent emissions differentiated by the 15 groups of substances (acetone, methanol, propanol, solvent naphtha, paraffins, alcohols, glycols, ester, aromates, ketones, aldehydes, amines, organic acids, cyclic hydrocarbons, and others). Substance specific carbon dioxide factors for these 15 substance groups have been created in Austria (see Table 4-27) on the basis of the carbon content and the stoichiometrically formed CO_2.

Table 4-27 - Substance specific carbon dioxide emission factors

Substances	CO_2 factor [kg CO_2/kg substance]	Substances	CO_2 factor [kg CO_2/kg substance]
Acetone	2.28	Glycols	1.82
Aldehydes	2.44	Ketones	2.45
Alcohols	1.91	Methanol	1.38
Alcohols/Propanols	2.20	Paraffins	3.14
Aromates	3.33	Residuals	0.92
Cydic Hydrocarbons	3.14	Solvent naphta	3.14
Ester	2.16	Glycols	1.82

In Austria the amount of carbon dioxide emissions was disaggregated to SNAP level 3 according to the share of solvents used and solvent emissions that were calculated in the context of the bottom up approach. In Table 4-27, the implied CO_2 Emission factors of Austria, which were also used for Luxembourg, as well as in Table 4-28, the carbon dioxide emissions of Category *3-Solvent and Other Product Use* for the years 1990 to 2015 are shown.

Table 4-28 - CO_2 emission of Category 2.D.3.1 Solvent and Other Product Use 1990–2015.

SNAP	0601	060101	060102	060103	060104	060105	060107	060108
Unit				Gg				
1990	4.31	0.04	0.187	1.311	0.211	0.896	0.531	1.132
1991	4.05	0.037	0.188	1.299	0.205	0.831	0.502	0.986
1992	3.76	0.034	0.186	1.267	0.2	0.762	0.47	0.847
1993	3.50	0.031	0.183	1.226	0.197	0.697	0.439	0.724
1994	3.19	0.028	0.177	1.162	0.194	0.627	0.403	0.605
1995	3.49	0.029	0.203	1.309	0.238	0.673	0.441	0.601
1996	3.43	0.028	0.195	1.269	0.241	0.702	0.407	0.59
1997	3.37	0.028	0.188	1.228	0.244	0.729	0.374	0.579
1998	3.09	0.025	0.17	1.112	0.231	0.707	0.32	0.53
1999	3.14	0.025	0.17	1.112	0.241	0.755	0.301	0.536
2000	3.00	0.024	0.159	1.045	0.237	0.757	0.265	0.508
2001	2.96	0.026	0.17	1.118	0.242	0.599	0.283	0.525
2002	3.10	0.031	0.192	1.266	0.261	0.456	0.32	0.574
2003	2.45	0.027	0.165	1.086	0.213	0.213	0.274	0.477
2004	3.47	0.041	0.225	1.495	0.288	0.309	0.378	0.733
2005	3.54	0.044	0.223	1.489	0.282	0.322	0.377	0.8
2006	2.87	0.034	0.18	1.258	0.233	0.28	0.327	0.559
2007	2.43	0.027	0.152	1.106	0.2	0.252	0.294	0.397
2008	3.48	0.037	0.217	1.643	0.29	0.383	0.446	0.46
2009	3.09	0.031	0.192	1.51	0.262	0.36	0.418	0.312
2010	2.56	0.025	0.159	1.296	0.22	0.315	0.365	0.179
2011	2.82	0.027	0.175	1.431	0.243	0.347	0.403	0.198
2012	3.18	0.031	0.197	1.609	0.273	0.391	0.453	0.223
2013	3.35	0.032	0.208	1.696	0.288	0.412	0.478	0.235
2014	2.88	0.028	0.178	1.456	0.247	0.354	0.41	0.202
2015	3.36	0.032	0.208	1.700	0.289	0.413	0.479	0.235

SNAP	0602	060201	060202	060203	060204
Unit			Gg		
1990	4.38	3.161	0.024	0	1.197
1991	4.12	2.88	0.026	0	1.21
1992	3.81	2.587	0.028	0	1.195
1993	3.50	2.307	0.029	0	1.167
1994	3.15	2.007	0.029	0	1.111
1995	3.36	2.066	0.035	0	1.256
1996	3.35	1.934	0.036	0	1.383
1997	3.35	1.809	0.037	0.001	1.504
1998	3.14	1.587	0.036	0.001	1.519
1999	3.26	1.539	0.038	0.001	1.682
2000	3.18	1.404	0.038	0.002	1.741

SNAP	0602	060201	060202	060203	060204
Unit			Gg		
2001	3.38	1.398	0.038	0.002	1.941
2002	3.80	1.473	0.041	0.002	2.281
2003	3.24	1.176	0.034	0.001	2.024
2004	3.96	1.126	0.046	0.002	2.785
2005	3.50	0.679	0.045	0.002	2.772
2006	2.94	0.552	0.037	0.001	2.35
2007	2.57	0.467	0.032	0.001	2.071
2008	3.80	0.669	0.046	0.001	3.085
2009	3.48	0.594	0.042	0.001	2.843
2010	2.97	0.493	0.035	0	2.444
2011	3.28	0.544	0.039	0	2.699
2012	3.69	0.612	0.043	0	3.035
2013	3.89	0.645	0.046	0	3.199
2014	3.34	0.554	0.039	0	2.747
2015	3.90	0.647	0.046	0	3.207

SNAP	0603	060305	060306	060307	060308	060309	060310	060311	060312	060314
Unit					Gg					
1990	2.22	1.751	0.031	0.214	0.107	NO	0.007	0.003	0.013	0.093
1991	2.18	1.751	0.029	0.19	0.097	NO	0.007	0.003	0.013	0.088
1992	2.11	1.732	0.025	0.161	0.083	NO	0.007	0.003	0.012	0.082
1993	2.09	1.708	0.022	0.173	0.09	NO	0.007	0.003	0.012	0.077
1994	2.02	1.654	0.019	0.17	0.088	NO	0.007	0.003	0.012	0.07
1995	2.39	1.912	0.019	0.236	0.12	NO	0.008	0.003	0.014	0.077
1996	2.11	1.671	0.021	0.203	0.113	NO	0.007	0.004	0.013	0.078
1997	1.87	1.436	0.022	0.195	0.12	NO	0.005	0.004	0.011	0.08
1998	1.49	1.131	0.022	0.145	0.1	NO	0.004	0.004	0.009	0.076
1999	1.29	0.955	0.023	0.118	0.095	NO	0.003	0.005	0.009	0.08
2000	1.05	0.724	0.024	0.109	0.103	NO	0.002	0.005	0.007	0.078
2001	1.29	0.958	0.031	0.111	0.102	NO	0.002	0.004	0.005	0.079
2002	1.64	1.279	0.041	0.12	0.106	NO	0.002	0.004	0.003	0.084
2003	1.55	1.253	0.04	0.098	0.084	NO	0.002	0.003	0	0.068
2004	2.04	1.664	0.045	0.13	0.111	NO	0.002	0.004	0.001	0.081
2005	1.95	1.602	0.036	0.126	0.107	NO	0.002	0.004	0.001	0.071
2006	1.39	1.085	0.025	0.098	0.108	NO	0.002	0.003	0	0.07
2007	1.02	0.735	0.018	0.079	0.11	NO	0.001	0.003	0	0.07
2008	1.23	0.793	0.021	0.109	0.183	NO	0.002	0.004	0	0.115
2009	0.89	0.473	0.015	0.092	0.186	NO	0.002	0.004	0	0.116
2010	0.57	0.202	0.009	0.073	0.173	NO	0.001	0.004	0	0.107
2011	0.63	0.224	0.01	0.08	0.191	NO	0.001	0.004	0	0.118
2012	0.71	0.251	0.011	0.09	0.215	NO	0.002	0.004	0	0.133
2013	0.74	0.265	0.011	0.095	0.226	NO	0.002	0.005	0	0.14
2014	0.64	0.228	0.01	0.082	0.194	NO	0.002	0.004	0	0.12
2015	0.75	0.266	0.011	0.095	0.227	NO	0.002	0.005	0	0.14

SNAP	0604	060403	060404	060405	060406	060407	060408	060411	060412
Unit					Gg				
1990	4.50	1.534	0	0	0.025	0.046	1.922	0.608	0.363
1991	4.46	1.457	0	0	0.026	0.047	1.972	0.621	0.337
1992	4.34	1.37	0	0	0.025	0.048	1.969	0.62	0.31
1993	4.19	1.286	0	0	0.025	0.048	1.937	0.614	0.284
1994	3.96	1.185	0	0	0.024	0.046	1.855	0.593	0.256
1995	4.45	1.305	0	0	0.028	0.054	2.104	0.679	0.275
1996	4.51	1.274	0.002	0	0.027	0.053	2.181	0.687	0.289
1997	4.58	1.244	0.004	0	0.027	0.053	2.253	0.695	0.302
1998	4.34	1.138	0.005	0	0.025	0.049	2.175	0.658	0.295
1999	4.55	1.151	0.007	0	0.025	0.05	2.314	0.687	0.317
2000	4.48	1.095	0.008	0	0.024	0.049	2.313	0.676	0.32
2001	4.61	1.142	0.01	0	0.035	0.05	2.388	0.688	0.301
2002	5.03	1.262	0.012	0	0.05	0.053	2.612	0.742	0.297
2003	4.16	1.058	0.011	0	0.051	0.043	2.169	0.607	0.221
2004	5.53	1.353	0.016	0	0.051	0.058	2.946	0.82	0.282
2005	5.32	1.254	0.016	0	0.034	0.056	2.899	0.803	0.261
2006	4.44	0.973	0.013	0	0.026	0.046	2.422	0.662	0.298
2007	3.86	0.784	0.011	0	0.021	0.04	2.107	0.569	0.325
2008	5.66	1.068	0.015	0	0.029	0.058	3.098	0.827	0.569
2009	5.15	0.9	0.013	0	0.024	0.052	2.822	0.745	0.597
2010	4.38	0.706	0.011	0	0.019	0.044	2.4	0.626	0.571
2011	4.83	0.78	0.012	0	0.021	0.048	2.65	0.692	0.63
2012	5.44	0.877	0.014	0	0.023	0.054	2.98	0.778	0.709
2013	5.73	0.924	0.014	0	0.025	0.057	3.141	0.82	0.747
2014	4.92	0.793	0.012	0	0.021	0.049	2.698	0.704	0.641
2015	5.74	0.926	0.014	0	0.025	0.057	3.149	0.82	0.749

Table 4-29 - Implied CO_2 Emission factors for Category 2.D.3.1 Solvent and Other Product Use 1990–2015.

SNAP	060101	060102	060103	060104	060105	060107	060108
Unit				kg/Mg Solvent			
1990	2.61	2.57	2.61	2.36	2.39	2.50	1.91
1991	2.42	2.58	2.58	2.29	2.21	2.36	1.66
1992	2.22	2.56	2.52	2.23	2.03	2.21	1.43
1993	2.02	2.52	2.44	2.19	1.86	2.06	1.22
1994	1.82	2.45	2.33	2.19	1.68	1.91	1.03
1995	1.70	2.47	2.30	2.35	1.59	1.84	0.90
1996	1.59	2.33	2.23	2.26	1.50	1.74	0.82
1997	1.60	2.37	2.31	2.32	1.51	1.77	0.81
1998	1.57	2.35	2.35	2.34	1.49	1.76	0.78
1999	1.54	2.33	2.39	2.35	1.47	1.74	0.75
2000	1.53	2.34	2.45	2.39	1.47	1.75	0.73
2001	1.53	2.34	2.45	2.39	1.47	1.75	0.73
2002	1.53	2.34	2.45	2.39	1.47	1.75	0.73
2003	1.53	2.34	2.45	2.39	1.47	1.75	0.73
2004	1.53	2.34	2.45	2.39	1.47	1.75	0.73
2005	1.53	2.34	2.45	2.39	1.47	1.75	0.73

SNAP	060101	060102	060103	060104	060105	060107	060108
Unit				kg/Mg Solvent			
2006	1.53	2.34	2.45	2.39	1.47	1.75	0.73
2007	1.53	2.34	2.45	2.39	1.47	1.75	0.73
2008	1.53	2.34	2.45	2.39	1.47	1.75	0.73
2009	1.53	2.34	2.45	2.39	1.47	1.75	0.73
2010	1.53	2.34	2.45	2.39	1.47	1.75	0.73
2011	1.53	2.34	2.45	2.39	1.47	1.75	0.73
2012	1.53	2.34	2.45	2.39	1.47	1.75	0.73
2013	1,53	2,34	2,45	2,39	1,47	1,75	0,73
2014	1.53	2.34	2.45	2.39	1.47	1.75	0.73
2015	1.53	2.34	2.45	2.39	1.47	1.75	0.73

SNAP	060201	060202	060203	060204
Unit		kg/Mg Solvent		
1990	2.47	1.10	1.94	1.96
1991	2.25	1.18	1.75	1.98
1992	2.02	1.25	1.56	1.95
1993	1.80	1.29	1.38	1.91
1994	1.58	1.31	1.20	1.83
1995	1.43	1.38	1.08	1.82
1996	1.31	1.34	1.01	1.74
1997	1.29	1.39	1.00	1.79
1998	1.24	1.42	0.98	1.79
1999	1.20	1.44	0.96	1.79
2000	1.16	1.47	0.94	1.80
2001	1.16	1.47	0.94	1.80
2002	1.16	1.47	0.94	1.80
2003	1.16	1.47	0.94	1.80
2004	1.16	1.47	0.94	1.80
2005	1.16	1.47	0.94	1.80
2006	1.16	1.47	0.94	1.80
2007	1.16	1.47	0.94	1.80
2008	1.16	1.47	0.94	1.80
2009	1.16	1.47	0.94	1.80
2010	1.16	1.47	0.94	1.80
2011	1.16	1.47	0.94	1.80
2012	1.16	1.47	0.94	1.80
2013	1,16	1,47	0,94	1,80
2014	1.16	1.47	0.94	1.80
2015	1.16	1.47	0.94	1.80

SNAP	060305	060306	060307	060308	060309	060310	060311	060312	060314
Unit					kg/Mg Solvent				
1990	2.88	0.99	2.77	1.78	2.68	0.03	2.18	2.11	1.40
1991	2.88	0.90	2.46	1.61	2.45	0.03	2.23	2.11	1.32

SNAP	060305	060306	060307	060308	060309	060310	060311	060312	060314
Unit					kg/Mg Solvent				
1992	2.85	0.80	2.09	1.38	2.11	0.03	2.22	2.09	1.23
1993	2.81	0.71	2.24	1.49	2.27	0.03	2.19	2.07	1.15
1994	2.75	0.61	2.23	1.47	2.24	0.03	2.12	2.05	1.06
1995	2.79	0.54	2.71	1.76	2.65	0.03	2.13	2.14	1.02
1996	2.66	0.52	2.49	1.62	2.45	0.03	2.05	2.04	0.95
1997	2.71	0.54	2.77	1.80	2.72	0.03	2.12	2.09	0.95
1998	2.72	0.54	2.53	1.65	2.50	0.03	2.14	2.11	0.93
1999	2.73	0.54	2.34	1.53	2.32	0.03	2.15	2.13	0.91
2000	2.77	0.55	2.69	1.78	2.68	0.03	2.18	2.19	0.89
2001	2.77	0.55	2.69	1.78	2.68	0.03	2.18	2.19	0.89
2002	2.77	0.55	2.69	1.78	2.68	0.03	2.18	2.19	0.89
2003	2.77	0.55	2.69	1.78	2.68	0.03	2.18	2.19	0.89
2004	2.77	0.55	2.69	1.78	2.68	0.03	2.18	2.19	0.89
2005	2.77	0.55	2.69	1.78	2.68	0.03	2.18	2.19	0.89
2006	2.77	0.55	2.69	1.78	2.68	0.03	2.18	2.19	0.89
2007	2.77	0.55	2.69	1.78	2.68	0.03	2.18	2.19	0.89
2008	2.77	0.55	2.69	1.78	2.68	0.03	2.18	2.19	0.89
2009	2.77	0.55	2.69	1.78	2.68	0.03	2.18	2.19	0.89
2010	2.77	0.55	2.69	1.78	2.68	0.03	2.18	2.19	0.89
2011	2.77	0.55	2.69	1.78	2.68	0.03	2.18	2.19	0.89
2012	2.77	0.55	2.69	1.78	2.68	0.03	2.18	2.19	0.89
2013	2,77	0,55	2,69	1,78	2,68	0,03	2,18	2,19	0,89
2014	2.77	0.55	2.69	1.78	2.68	0.03	2.18	2.19	0.89
2015	2.77	0.55	2.69	1.78	2.68	0.03	2.18	2.19	0.89

SNAP	060403	060404	060405	060406	060407	060408	060411	060412
Unit					kg/Mg Solvent			
1990	1.98	0.66	2.55	2.70	1.89	1.87	2.15	2.13
1991	1.88	0.67	2.42	2.72	1.95	1.92	2.19	1.98
1992	1.77	0.66	2.29	2.69	1.96	1.92	2.19	1.82
1993	1.66	0.65	2.16	2.66	1.96	1.89	2.17	1.67
1994	1.54	0.64	2.02	2.59	1.93	1.82	2.11	1.52
1995	1.49	0.66	1.97	2.61	1.96	1.82	2.12	1.43
1996	1.41	0.63	1.86	2.51	1.88	1.74	2.04	1.36
1997	1.43	0.64	1.88	2.58	1.94	1.79	2.10	1.37
1998	1.42	0.65	1.86	2.60	1.96	1.80	2.11	1.36
1999	1.40	0.65	1.84	2.61	1.98	1.80	2.12	1.35
2000	1.40	0.66	1.84	2.65	2.03	1.82	2.15	1.35
2001	1.40	0.66	1.84	2.65	2.03	1.82	2.15	1.35
2002	1.40	0.66	1.84	2.65	2.03	1.82	2.15	1.35
2003	1.40	0.66	1.84	2.65	2.03	1.82	2.15	1.35
2004	1.40	0.66	1.84	2.65	2.03	1.82	2.15	1.35
2005	1.40	0.66	1.84	2.65	2.03	1.82	2.15	1.35
2006	1.40	0.66	1.84	2.65	2.03	1.82	2.15	1.35
2007	1.40	0.66	1.84	2.65	2.03	1.82	2.15	1.35
2008	1.40	0.66	1.84	2.65	2.03	1.82	2.15	1.35

SNAP	060403	060404	060405	060406	060407	060408	060411	060412
Unit				kg/Mg Solvent				
2009	1.40	0.66	1.84	2.65	2.03	1.82	2.15	1.35
2010	1.40	0.66	1.84	2.65	2.03	1.82	2.15	1.35
2011	1.40	0.66	1.84	2.65	2.03	1.82	2.15	1.35
2012	1.40	0.66	1.84	2.65	2.03	1.82	2.15	1.35
2013	1,40	0,66	1,84	2,65	2,03	1,82	2,15	1,35
2014	1.40	0.66	1.84	2.65	2.03	1.82	2.15	1.35
2015	1.40	0.66	1.84	2.65	2.03	1.82	2.15	1.35

4.5.3.1.5 Uncertainties and time-series consistency

The error values which are assumed on the various calculations are as given (IPCC 2006 Guidelines Vol3 Ch5 p. 5.17):

- Activity data uncertainty 50%
- Emission factor uncertainty 50%

4.5.3.1.6 Source specific QA/QC and verification

The calculations of the data for category 3 are embedded in the overall QA/QC-system of the GHG inventory of which important elements include:

- Are the correct values used (check for transcription errors, …)?
- Check of plausibility of input data (time-series, order of magnitude, …)
- Is the data set complete for the whole time series?
- Check of calculations, units ...
- Check of plausibility of results (time-series, order of magnitude, …)
- Correct transformation/transcription into CRF
- Where possible, data is checked with data from other sources, order of magnitude checks, …
- Are all references clearly made?
- Are all assumptions documented?

Source-specific elements of QA/QC for Solvent and Other Product Use include:

a) Bottom-up checks on:

Input data and emission factors:

- check for the plausibility of the activity data and their trend and check for plausibility of the emission factors as well as the related input data and their trends

- check documentation of the most important reasons for changes and non-changes of activity data
- check if these changes or non-changes of activity data fit to trends of underlying conditions
- if checks do not allow any explanation, further check of the used statistics and their estimates and/or communication with the data providers
- check of input data for completeness

Emissions:

- check the correctness of all equations in the calculation files
- check the correctness of all intermediate results
- check the plausibility of the results and their trends related to activity data and emission factors
- check the correctness of the transfer of all data and results

b) Top-down checks include:

- Comparison of the used activity data with those from other statistics: STATEC publication and EUROSTAT database.
- Comparison of the used activity data with those from relevant plant operators.
- Comparison of the used emission factors and underlying input data with those of other data sources (*e.g.* from literature, results in NIRs of other comparable regions, IPCC default values).

4.5.3.1.7 Category-specific recalculations including changes made in response to the review process

Table 4-30 presents the main revisions and recalculations done since submission 2013v1.2 relevant to IPCC category *3 – Solvents and Other Product Use* which are done also in response to the review process[120]: country-specific data were used to update the pillar years 2005 and 2010 in bottom-up approach.

Table 4-30 – Recalculations done since submission 2016v1

GHG source & sink category	Revisions 2016v1 ➔ 2017v1.2	Type of revision
2.D.3.1	update of data of production statistics, import and export statistics update of emission factors and solvent content update of plant specific, information from associations of industries and statistical data for "general aspects" and "specific aspects" .	updated 2.D.3.1

120 ARR 2010, § 52 Solvent and other product use - CO_2: Luxembourg bases its CO_2 emission estimates for this category on AD from Luxembourg using an implied CO_2 EF from Austria. The ERT reiterates the recommendation from the previous review that Luxembourg enhance the accuracy of these estimates by using country-specific data.

4.5.3.1.8 Category-specific planned improvements including those in response to the review process

There are currently no planned improvements to IPCC sub-category 2.D.3.1

4.5.3.2 Asphalt Roofing

This source category does not exist in Luxembourg.

4.5.3.3 Road Paving with Asphalt

This source category does not exist in Luxembourg.

4.5.3.4 Urea-based catalysts (2.D.3.2)

4.5.3.4.1 Source category description

In 2015, CO_2 emissions resulting from the use of urea-based catalysts in SCR-equipped vehicles was responsible for 1.74% of GHG emissions CO2e from industrial processes and product use and for 0.09% of the total GHG emissions in CO_2e (excluding LULUCF). Compared to 2014, emissions decreased by 10.64% to reach 9.51 Gg CO_2 in 2015. An overview of the related CO_2 emissions is provided in Table 4-31.

2.D.3.2 – Urea-based catalysts is not a key source with regard to CO_2 emissions.

Table 4-31 - CO_2 emissions trend, activity data and IEFs for IPCC sub-category 2.D.3.2 – Urea-based catalysts: 1990-2015.

2D3 - Urea-based catalysts			
Year	activity data (t)	CO_2 emissions (Gg)	implied emission factor (t CO_2/t)
1990	NO	NO	NA
1991	NO	NO	NA
1992	NO	NO	NA
1993	NO	NO	NA
1994	NO	NO	NA
1995	NO	NO	NA
1996	NO	NO	NA
1997	NO	NO	NA
1998	NO	NO	NA
1999	NO	NO	NA
2000	NO	NO	NA
2001	NO	NO	NA
2002	NO	NO	NA
2003	NO	NO	NA
2004	NO	NO	NA
2005	5 526	1.32	0.238
2006	13 409	3.20	0.238
2007	22 164	5.28	0.238
2008	32 677	7.79	0.238
2009	33 973	8.10	0.238
2010	42 400	10.11	0.238
2011	48 128	11.47	0.238
2012	46 708	11.13	0.238
2013	47 922	11.42	0.238
2014	44 655	10.64	0.238
2015	44 552	9.51	0.213
Trend 1990-2015	*NA*	*NA*	
Trend 2014-2015	*-0.23%*	*-10.64%*	

Total sales volumes or import/export data for urea-based catalysts are not available for Luxembourg. Therefore the NEMO model (details in Chapter 3.2.8.3.2.2) was used to estimate the consumption of AdBlue® by SCR-equipped vehicles (domestic and transiting/commuting fleet). Urea-based catalysts have been consumed by heavy duty vehicles since 2005 (EURO IV and higher) and since 2013 also by passenger cars (EURO 6).

4.5.3.4.1.1 Methodology

CO_2 emissions from urea-based catalysts used in SCR-equipped vehicles are calculated separately by the NEMO model (described in chapter 3.2.8.3.2.2.). This approach considers the specific operating condition of the SCR exhaust gas after-treatment system in any driving condition[121]. The calculation is based on the assumption that one mole of urea generates one mole of CO_2 and converts 0.9 mole of NO_x as illustrated by **Equation 4-1**.

Equation 4-1: Formula used by the NEMO model to determine CO_2 emissions from the use of AdBlue® in SCR-equipped vehicles.

$$CO_2\,[g] = \frac{(NO_{x,EO} - NO_{x,TP})[g]}{\underbrace{46\left[\frac{g}{mol}\right]}_{\text{molar mass } NO_2}} \cdot \left(\frac{1}{1 - s_{NH3,loss}}\right) \underbrace{\frac{1}{2}}_{CO_2 / NH_3 \text{ mole ratio}} \underbrace{44\left[\frac{g}{mol}\right]}_{\text{molar mass } CO_2}$$

With:

$NO_{x,EO}$: NO_x emissions (in NO_2 mass equivalent) at engine out

$NO_{x,TP}$: NO_x emissions (in NO_2 mass equivalent) at tailpipe

$s_{NH3,loss}$: share of NH_3 losses caused by NH_3 slip through SCR catalyst without NO_x conversion and by NH_3 not generated from urea. The value used for $s_{NH3,loss}$ is 10% (expert judgment by IVT Graz).

4.5.3.4.1.2 Emission factors

The CO_2 implied emission factor for urea-based catalysts is 0.238 t/t for the entire timeseries. This is equivalent to the default emission factor proposed in the IPCC guidelines[122].

4.5.3.4.1.3 Uncertainties and time-series consistency

The uncertainty for activity data is estimated to be +/−20% (expert judgement by TU Graz, 2015). The emission factor uncertainty is assumed to be 5%.

The timeseries is considered to be consistent.

4.5.3.4.2 Source-specific QA/QC and verification

There are no statistical recordings of activity data for AdBlue®.

The emission factor used by the NEMO model was compared to the default value proposed in the IPCC guidelines.

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[121] Rexeis M., Schwingshackl M., Dippold M., Hausberger S.: Emissionen aus Kalt- und Kühlstarts sowie aus AdBlue-Verwendung in SCR-Katalysatoren von Lkw, LNF, 2-Rädern sowie von mobilen Maschinen. Erstellt im Auftrag des Umweltbundesamtes GmbH. Bericht Nr.: I-24/201313/Rex Em 11/2013-679 vom 16.9.2013

[122] 2006 IPCC Guidelines, Volume 2, Chapter 3, p. 3.12

4.5.3.4.3 Category-specific recalculations including changes made in response to the review process

Based on a new study (Komobile, FTV, 2017), activity data for the years 2005-2014 has been revised. Mainly the size and distribution of the vehicle population employing urea-based catalyst has been revaluated, leading to the aforementioned revision.

4.5.3.4.4 Category-specific planned improvements including those in response to the review process

There are currently no planned improvements to IPCC sub-category 2.D.3.2.

4.6 Electronics industry (2.E)

4.6.1 Integrated circuit or semiconductor (2.E.1)

This source category does not exist in Luxembourg.

4.6.2 TFT flat panel display (2.E.2)

This source category does not exist in Luxembourg.

4.6.3 Photovoltaics (2.E.3)

This source category does not exist in Luxembourg.

4.6.4 Heat transfer fluid (2.E.4)

This source category does not exist in Luxembourg.

4.6.5 Other (as specified in table 2(II)) (2.E.5)

4.7 Product uses as substitutes for ODS (2.F)

Consumption of Halocarbons and SF_6 (2F)

The following sources have been identified:

- Refrigeration and air-conditioning (2.F.1)
  - Commercial refrigeration
  - Domestic refrigeration
  - Industrial refrigeration
  - Transport refrigeration
  - Mobile air-conditioning

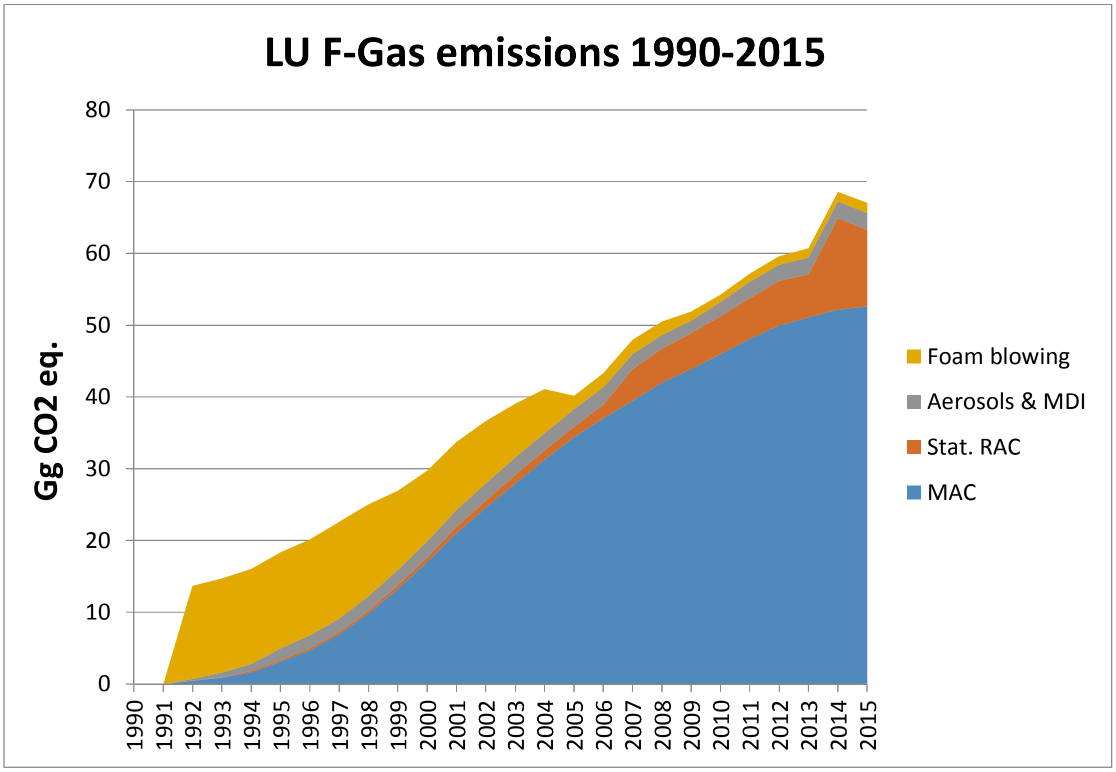
- Stationary air-conditioning
- Foam blowing agents (2.F.2)
  - Closed cells
  - Open cells
- Fire protection (2.F.3)
- Aerosols (2.F.4)
  - Metered dose inhalers
  - Other (please specify - one row per substance)
- Solvents (2.F.5)
- Other applications(9) (2.F.6)
  - Emissive
  - Contained

4.7.1 Source category description

This section describes the estimation of products uses as substitutes for ODS resulting from industrial processes (production, consumption). In 2015, this category represented 10.39% of the GHG emissions in CO_2e from industrial processes and 0.66% of the total GHG emissions in CO_2e (excluding LULUCF). This percentage was only 0.19% in 1995. As shown in Figure 4-12, the related emissions experienced an increase between 1995 and 2015 (+265%). Compared to 2014, emissions decreased by 2.22% to attain the level of 67.05 Gg CO_2 in 2015.

F-gas emission estimates are presented in Table 4-32.

Figure 4-12 – GHG emission trends for CRF Sector 2F – HFCs: 1990-2015



2F – Product uses as substitutes for ODS is a key source with regard to F-gas emissions since 2003: see Table 4-2 in Section 4.1.2.

Finally, although Luxembourg now reports emissions from 1990 onwards, it should be highlighted that 1995 was chosen as the base year for HFCs.

Table 4-32 – Estimated emissions of HFCs: 1990-2015

Year	2F -Product uses as substitutes for ODS	2F1 - Refrigeration and Air Conditioning Equipment (HFC)	2F1 - Stationary refrigeration and air conditioning	2F1 - Mobile refrigeration and air conditioning	2F2 - Foam Blowing (HFC)	2 F4 - Aerosols/ Metered Dose Inhalers (HFC)
	Gg CO_2 e					
1990	0.00	0.00	0.00	0.00	0.00	0.00
1991	0.00	0.00	0.00	0.00	0.00	0.00
1992	13.69	0.48	0.03	0.45	12.99	0.23
1993	14.71	0.92	0.05	0.87	13.10	0.70
1994	16.04	1.82	0.22	1.60	13.24	0.99
1995	18.37	3.35	0.24	3.11	13.38	1.65
1996	20.14	4.98	0.29	4.69	13.36	1.80
1997	22.62	7.23	0.32	6.91	13.47	1.92
1998	25.06	10.21	0.35	9.86	12.81	2.04
1999	26.92	13.77	0.51	13.26	10.99	2.15
2000	29.73	17.61	0.57	17.04	9.85	2.27
2001	33.75	21.93	0.89	21.04	9.45	2.37
2002	36.65	25.54	0.96	24.59	8.70	2.41
2003	39.04	29.10	1.20	27.90	7.49	2.46
2004	41.12	32.56	1.29	31.26	6.16	2.40
2005	40.18	35.86	1.46	34.39	1.87	2.46
2006	43.27	38.88	1.86	37.02	1.94	2.45
2007	47.99	43.85	4.38	39.47	2.02	2.12
2008	50.51	46.71	4.71	41.99	1.88	1.93
2009	51.91	48.87	4.99	43.87	1.31	1.73
2010	54.26	51.29	5.32	45.97	1.01	1.95
2011	57.18	53.79	5.67	48.12	1.12	2.27
2012	59.62	56.18	6.27	49.91	1.22	2.22
2013	60.70	57.06	5.98	51.08	1.29	2.34
2014	68.57	64.92	12.75	52.17	1.34	2.32
2015	67.05	63.27	10.65	52.62	1.43	2.35
Trend 1995-2015	*265%*	*1789%*	*4310%*	*1593%*	*-89%*	*42%*
Trend 2014-2015	*-2.22%*	*-2.54%*	*-16.47%*	*0.86%*	*7.27%*	*1.17%*

Source: Environment Agency

4.7.1.1 Methodology

The emissions of fluorinated greenhouse gases in Luxembourg were thoroughly re-assessed in 2014 in order to assure compliance with the 2006 IPCC reporting guidelines, to streamline data acquisition and processing, to include previously neglected applications and sub-applications, and to increase transparency of emissions estimations.

Generally speaking, emissions estimations in Luxembourg are based on emission-factor approaches. Due to highly incomplete records of chemical sales data (Econotec consultants 2010, importers inquiry 2014), mass-balance approaches are mostly inapplicable. Emission factors are predominantly derived from regional to global estimates. In some cases, it was possible to calculate country-specific emission factors. Activity data consisted in direct emission records (e.g. refrigeration manufacturing, industrial and commercial refrigeration), country-specific life-cycle approach data (e.g. mobile air conditioning) or, in the absence of country-specific records, regionally derived data (e.g. aerosols).For the first time, emissions from fluorinated ethers used as anaesthetics are estimated for Luxembourg as complementary information. Note, however, that fluorinated ethers are not among the mandatory sources of greenhouse gas emissions to be reported under the 2006 IPCC Reporting Guidelines, and were thus excluded from Luxembourg halocarbon and SF_6 emissions compilations. In the medical applications considered here, fluorinated ethers are completely emitted after use. Thus, consumption of fluorinated ethers was considered equal to emission.

4.7.1.1.1 Refrigeration and air-conditioning (2.F.1)

The following sub-applications have been identified:

- Fridge production
- Commercial and industrial refrigeration
- Stationary air conditioning
- Refrigerated transport
- Mobile air conditioning:
    - cars
    - buses
    - trucks
    - trains
    - agricultural and construction engines

Domestic refrigeration plays no significant role here. In fact, , the share of domestic fridges containing fluorinated greenhouse gases has been very low in Luxembourg since 1995, and considering an average refrigerant charge of 0,1 kg and an operation emission factor of 0,3 % (Schwarz 2005), emissions from the domestic refrigeration sub-application are, indeed, negligible and therefore omitted here.

Fridge production: A single fridge production plant, run by Dometic S.à.r.l., is currently being exploited in Luxembourg. The equipment produced is predominantly used for medical and other non-domestic purposes. Almost the entire production (99,5 %) is exported. Thus, the only relevant emissions to be considered are those occurring during manufacture.

On the basis of a six month emissions survey by Dometic in 2006, a manufacture emission of 2 kg of R134a was calculated for 2006. The resulting manufacture emissions factor was extrapolated to the years before and after 2006.

Commercial and industrial refrigeration: As part of the obligations introduced by Regulation (EC) No 842/2006 of the European Parliament and of the Council of 17 May 2006 on certain fluorinated greenhouse gases, leak checks are to be performed regularly for all equipment containing at least 3 kg of fluorinated greenhouse gases. Luxembourgian legislation requires the reports of the leak checks to be transmitted to the authorities at the Luxembourg Environmental Agency. Since almost all non-domestic refrigeration and air conditioning devices contain more than 3 kg of refrigerant, the leak tightness reports contribute to an extensive database covering almost the entire sector. This database was used as a basis for the emissions estimations. In order to account for the refrigeration devices containing less than 3 kg of refrigerant and thus not covered by the leak detection database, all emission values were increased by 10 %, which was assumed to adequately represent the share of the devices in question taking into account their low individual charges.

Given the nature of the information provided by the leak detection reports, stand-alone commercial refrigeration, medium and large commercial refrigeration and industrial refrigeration were lumped as commercial and industrial refrigeration.

In previous years, the record of leak detection reports was too patchy to be used as source of evidence. Significant efforts were made since to achieve a more thorough enforcement of the reporting obligation, with the result that a much more complete database is available. In order to test for the exhaustiveness of the reports, the retail refrigeration sector was chosen as a model system. In fact, the number of supermarkets and retail stores can be easily monitored, in contrast to the number of buildings equipped with air conditioning for example. Comparison with the leak detection coverage of the retail sector then provides an estimation of the database completeness.

A total of 65,8 % of the retail sector existing at the end of 2013 (except for small shops at service stations which mostly lack devices containing more than 3 kg of refrigerant) are covered by a leak detection report for 2013. Subtracting supermarkets equipped with refrigeration devices exclusively using natural refrigerants, accounting for an estimated 18 % of the Luxembourgian retail sector, a completeness of 72 % can be assumed. The remaining 28 % are extrapolated in the present emissions estimations. The 72 % completeness quota is extended to all other refrigeration and air conditioning sub-applications covered by the leak inspection database, provided that the retail sector is representative in terms of reports exhaustiveness. Completeness has been revaluated for the years 2014 (80%) and 2015 (89%).

Assuming a life span of 20 years per device (Schwarz 2005), the evolution of the refrigeration equipment population could be approximated rather faithfully. All equipment constructed before 1993 is assumed to have been converted to hydrofluorocarbon (HFC) refrigerants in 1993 (which approximates the time of introduction of the HFCs as alternatives to the ozone depleting refrigerants), and the respective HFC charges to have entered the population in 1993. The charges of the devices for which the leak inspection reports provided no year of construction were totalled, divided by the number of years since the first appearance of the respective refrigerant in the Luxembourgian refrigeration population and added to the charges of the years in question. These measures are deemed temporary awaiting improvement of the reporting accuracy.

The non-domestic refrigeration sector presents an overwhelming span of refrigerant charges, ranging from a few kilograms to more than half a metric ton. Thanks to the leak inspection reports which indicate the charge of the device checked, the total amount of refrigerant being used in a particular year can be directly monitored rather than approximated on the basis of average refrigerant charges. In combination with the year of manufacture as indicated by the tightness reports and an assumed 20 years life span, the total amount of refrigerant entering the Luxembourgian refrigeration device population per year can be directly monitored as well.

Leak inspection reporting precisely indicates the amount of refrigerant emitted per device. As a result, operation emissions could be directly monitored rather than implied through application of an emission factor, at least since 2012 when the database attained satisfying completeness. On the basis of the total amount of refrigerant used per year and the total amount of refrigerant emitted during operation in the same year, implied emission factor were calculated for individual refrigerants and applied to the respective pre-2012 stocks.

Emissions during manufacture and decommissioning: Most of the non-domestic refrigeration devices are assembled (or at least filled with refrigerant for the first time) and decommissioned in Luxembourg. Since the share of pre-filled importations and decommissioned but non-emptied exportations is unknown, is assumed.

Unfortunately, the leak inspection reports provide no insights on emissions during manufacture and decommissioning. In line with the default emission factors of the 2006 IPCC reporting guidelines for developed countries, and assuming a conservative 100 % rate of manufacture and decommissioning of equipment in Luxembourg, a manufacture emission factor of 0,5 % and a decommissioning emission factor of 30 % were adopted.

Stationary air conditioning: Since data on residential and commercial air conditioning are extracted from the same leak inspection database as the data on commercial and industrial refrigeration, the approaches employed were the same. In line with the default emission factors of the 2006 IPCC reporting guidelines for developed countries, a manufacture emission factor of 0,2 % and a decommissioning emission factor of 20 % were adopted.

Refrigerated transport (RT): As a result of the recent re-assessment of fluorinated greenhouse gas emissions, annual registration figures of new RT vehicles for the years 1995-2014 were acquired.

The here-employed approach is based on the weight-class-specific characteristics used by Schwarz (2005) for the German model combined with Luxembourg-specific new registration figures and the relative shares of the weight classes. In order to comply with this model, relative shares of weight classes in the Luxembourgian general truck and van population were applied to annual new RT vehicle registrations data. The average life span of a RT vehicle is assumed to equal seven years.

Manufacture and decommissioning of RT equipment does occur in Luxembourg but at a very low level compared to importations and exportations (Carrosserie Comes & Cie 2014). Corresponding emissions are thus considered negligible.

Evolution of the RT vehicle population: are undifferentiated in terms of weight class. by Schwarz (2005), who subdivided German RT vehicles into the classes < 2 - 5 t, 5 - 9 t, 9 - 22 t and > 22 t,. These shares are assumed to approximate the composition of the Luxembourgian RT vehicle population. As for the truck MAC model,

Refrigerant type and average charge per RT vehicle: Schwarz (2005) elaborated a model taking into account the average charge per vehicle for each weight class and the respective shares of the predominantly used refrigerants (R134a, R404A and, since 1997, R410A):

Refrigerant type, average charge and share in RT equipment for the different weight classes									
Weight class	< 2 - 5 t	5 - 9 t		9 - 22 t			> 22 t		
Refrigerant	134a	134a	404A	134a	404A	410A	410A	134a	404A
Average charge (kg)	2,0	2,5	2,5	5	4	4	9	6,75	6,75
Share	100 %	50 %	50 %	10 %	10 %	80 %	10 %	5 %	85 %

Since no country-specific data in this respect were available and since there was no reason to assume that the Luxembourgian situation significantly deviates from the German one, the model by Schwarz (2005) was applied to the Luxembourgian RT vehicle population.

Given the exclusively commercial use of RT vehicles and the often highly temperature-sensitive freight, thorough and regular technical maintenance is assumed, implying a 100 % filling level. RT vehicles were assumed to leave the population with a filling of 85 %, in line with the annual loss through operation emission of 15 % (Schwarz 2005).

Mobile air conditioning (MAC):

Car MACs: In spite of relatively low average refrigerant charges (generally less than 1 kg), car MACs count among the most important sources of fluorinated greenhouse gas emissions. Luxembourg is no exception in this respect, considering its large and comparatively modern and thus well-equipped car population. A noteworthy particularity, however, is the lack of car manufacture and decommissioning facilities. All new cars are imported and almost all used cars are exported before scrapping. As a result, the only emissions to take into account for the Luxembourg car MAC sector are operation emissions.

The number of newly entering cars is provided as the number of new registrations by the STATEC records. The mean lifespan of a car in Luxembourg was found to be approximately 7 years by Econotec consultants (2010). Given the similarity between the Luxembourgian and the German car populations, the evolution of the MAC share suggested by Schwarz and Fischer (2009) is adopted here and considered to have reached saturation at 96% since 2005.

Schwarz (1996, 2005) traced a continuous decrease in the average refrigerant charge per car between 1992 until 2002, as a result of an increasing number of smaller cars being equipped with MAC but also a as a result of technical progress. For the trend beyond 2002, the data provided by Clodic (2006) was used and extrapolated. Here, advantage is taken of the brand-specific STATEC record of new registrations for the years 2005 until 2012, combined with the Behr Hella Service GmbH (2012) record of refrigerant charges per car model. Individual charges were averaged per brand, considering the models manufactured between 2005 and 2012. The average refrigerant charge per brand was then used in combination with the share of the individual brands in the Luxembourgian car population to calculate the average refrigerant charge per car of the Luxembourgian population for each year from 2005 to 2012.

The results document a slight decrease from 654 g per car in 2005 to 647 g in 2009, followed by a slight increase to 652 g per car in 2012. These values are well in line with the trend from 1992 to 2002 (Schwarz 1996, 2005) and a population with a high share of large, high-capacity cars. Unless significant shifts in the brand-specific composition of the population occur, the 2012 value of 652 g per car was here considered to hold true for 2013, at least preliminarily (see below).

During the first two years following manufacture, annual refilling of car ACs was assumed for guarantee service reasons. During the following years, car ACs were assumed to be only refilled when considered necessary, i.e. upon tangibly reduced performance. As shown by Clodic (2006), car AC performance only drops after the loss of approximately half of the refrigerant. With an annual regular emission rate of 8,8 % (see below), and a mean life span of seven years, cars in Luxembourg can be assumed to be exported before refilling after the two years guarantee is deemed necessary. In order to take this refilling pattern into account, an average filling level of 81 % is assumed, resulting from two years of 100 % filling, followed by five years of continuous loss without refilling. For the same reason, cars leaving the population after seven years are assumed to contain 59 % of the original refrigerant charge.

Schwarz (2007) used an operation emission factor of 10 %, resulting from an empirically determined factor of 8,8 % for intact ACs taking into account leakage from defective systems. Since there is no reason to assume that the Luxembourgian car population significantly differs from the car population used to determine the operation emission factor, the 10 % value is adopted here.

As a result of the EU MAC Directive (Directive 2006/40/EC of the European Parliament and of the Council of 17 May 2006 relating to emissions from air-conditioning systems in motor vehicles and amending Council Directive 70/156/EEC) banning refrigerants with a GWP exceeding 150 for ACs of newly registered car types, with a temporary exemption until 31 December 2012 (European Commission 2012), 5 % of all newly registered cars with an AC in 2013 were assumed to use a refrigerant other than R134a and were thus excluded from the emissions estimations. The 5 % assumption results from expert judgment implying an average 10 years life span of a car type and taking into account the resilience of certain car manufacturers to abandon R134a.

Bus and coach MACs: Emissions estimations for bus and coach MACs are basically similar to those of car MACs, with a few exceptions. As for cars, no manufacturing or decommissioning activities take place in Luxembourg. Accordingly, no manufacturing or decommissioning emissions are to be taken into account. The average life span of buses and coaches in Luxembourg was found to evolve around 7 years, as suggested by expert judgment from bus company representatives.

The bus operating companies furthermore confirmed that the vast majority of buses and coaches operated since 1995 have been equipped with MAC. One operator reached the 100 % MAC quota for his bus population in 1997, starting with 25 % in 1995, and a second one had no bus with MAC in 1995, reaching the 100 % quota only in 2007. As a result, a MAC quota of 70 % is assumed for the Luxembourg bus and coach population in 1995, increasing to 80 % in 1997 and then gradually increasing to 100 % in 2007. In order to account for the rise of R134a since its introduction in the bus MAC domain in 1993 (Schwarz 2005), an extrapolated quota evolution of 0 % in 1992, 30 % in 1993 and 70% in 1994 was adopted.

Bus and coach MACs contain much higher amounts of refrigerant than car MACs, owing to the much longer pipes. Individual charges, however, vary considerably, depending on the size and the type of the bus. Minibuses generally contain around 2 kg of refrigerant per vehicle, while the large high standard coaches require 15 kg of refrigerant. According to the information provided by the bus companies in Luxembourg, however, even within the same type of standard 14 m coach, charges range from 4,9 kg to 15 kg per vehicle, depending on technical specificities. Buses with separate conductor air conditioning for example generally contain more refrigerant.

In order to account for the high diversity of refrigerant charges per vehicle, an average value of 10 kg is adopted here, in line with the estimated average provided by the bus companies. Minibuses were assumed to range among the bus and coach figures rather than the car estimations. Although this is likely to result in overestimated emission values, a conservative approach is warranted in the absence of a more type-specific bus and coach population survey.

According to the bus company representatives, MACs of buses and coaches are generally refilled every year. In some cases, annual refilling is even part of maintenance obligations imposed by the manufacturers. This implies a 100 % filling level from registration to removal from service. Buses are assumed to leave the population with a 86 % filling level, in line with an annual loss of 14 %.

Figures of refrigerant consumption for maintenance provided by the bus companies suggest annual operation emission factors between 10 and 14 %. Ökorecherche (2007) found operation emission rates of 15 % for older buses and 13,7 % for younger ones (registered after 2000). An emission factor of 14 % is therefore adopted here to account for both the published figures and the empirical data provided by operators.

Truck MACs: Truck MACs follow the same principles of emissions estimations as car and bus/coach MACs. Again, only operation emissions are relevant in the case of Luxembourg. Estimations were based on a subdivision in three weight classes (vans, small trucks, large trucks) with individual MAC quota, refrigerant charge and operation emission factor figures respectively, following the model employed by Schwarz (2005).

Data on new weight-class specific truck registrations are extracted from the STATEC database. For the years since 1997, registration figures are subdivided into several weight classes. For the years before 1997, the trend of the relative shares in new registrations of the three weight classes of Schwarz (2005) is extrapolated to the weight-unspecific truck and van registrations of the respective years. In the absence of specific data, an average life span of seven years is assumed for trucks, in analogy to the car and bus/coach models.

Schwarz (2005) provided MAC quota figures for all three truck weight classes in Germany for the years 1993-2002. For the large trucks, the trend seems to meaningfully reflect the situation in Luxembourg and is therefore applied here in the absence of country-specific data. MAC quota figures after 2002 are extrapolated to attain a hypothetical saturation value of 90 % in 2005.

Since the equipment standard of the Luxembourgian vehicle population is generally above the European average, MAC quota figures for smaller trucks and vans provided by Schwarz (2005) seem too low. Country-specific data could not be collected because the presence or absence of a MAC is not recorded upon registration (SNCT pers. comm.). It was assumed that the MAC quota evolution of smaller trucks in Luxembourg was best reflected by that of the larger trucks. In the case of the vans, in contrast, the same trend as for cars was assumed.

According to Schwarz (2005), refrigerant charges have remained at constant values of 1 kg for small trucks and 1,2 kg for large trucks since 1993. Van MACs, in contrast, have undergone a decrease in refrigerant charge from 1,2 kg in 1993 to 0,85 kg in 2002. In line with the Behr Hella Service GmbH (2012) refrigerant charge data for various vehicle types, a further decrease to 0,8 kg per van by 2013 was adopted. Intermediate values between 2002 and 2013 were interpolated. A truck is assumed to leave the population with an average filling level of 86,5 %, in line with a combined average operation emission factor of 13,5 %.

Due to the predominantly commercial use of trucks, a more thorough and regular technical maintenance than for cars was assumed, resulting in an annual refilling of MACs and thus an effective charge of 100%, except for the last year before leaving the population.

Again, in the absence of country-specific data on refrigerant loss during operation, the emission factors determined by Schwarz (2005) on the basis of a survey on the German truck population were adopted. Vans were assumed to have the same operation emission factor as cars (10 %), as a result of technical similarity. Truck MACs, in contrast, are confronted with longer operation times and higher mechanical stress, and are thus assigned an emission factor of 15 %.

Tractor and engine MACs: Emissions estimations for MACs of tractors and engines (e.g. harvesters) are basically similar to those of truck MACs, with two different categories (tractors and engines) each with individual MAC quotas, refrigerant charges and emission factors. A similar approach to that of truck MACs, including calculation of combined variables, is therefore proposed.

All data on newly registered tractors and engines are extracted from the STATEC database. In the absence of specific data, an average life span of seven years is assumed for tractors and engines, in analogy to the car and bus/coach models.

Data on MAC quota were adopted from Schwarz (2005), who found a very steep rise since the introduction of R134a in the MAC sector to 75 % in 1994 and eventually 95 % in 2002 for engines, and a more gentle and gradual rise to 70 % in 2002 for tractors. These trends were assumed to hold true for the Luxembourgian tractor and engine populations, with pre-1994 data extrapolated to 0 % in 1992 in line with an introduction of R134a as standard MAC refrigerant in 1993 (Schwarz 2005), and post-2002 data assumed constant at 95 % for engines and extrapolated to reach 95 % in 2005 for tractors.

The average refrigerant charges of 1,44 kg per tractor and 1,6 kg per engine provided by Schwarz (2005) were adopted in the absence of country-specific data. Due to the largely commercial use of tractors and engines and the strong seasonal concentration of operation time, technical maintenance was assumed to be more thorough and regular than for cars, resulting in an annual refrigerant refilling and thus a 100 % filling level. Tractors and engines were assumed to leave the population with a filling level of 83 %, in line with an average operation emission factor of 17 % for the combined tractor and engine sector.

No country-specific data on operation emission factors were available, which is why the figures for the German tractor and engine populations provided by Schwarz (2005) (15 % for tractors and 25 % for engines) were adopted.

Rail vehicle MACs: Detailed annual data on rail vehicles with MAC entering and leaving the population, indicating individual refrigerant charges, were provided by the sole national railway operator.

It is assumed that all rail vehicles are subject to regular technical maintenance and thus refilled at least annually, implying a filling level of 100 %.

No construction or dismantling of rail vehicles takes place in Luxembourg. As a result, only emissions during operation are relevant. No country-specific data were available for operation emission factors. Schwarz (2005) used 15 % for German rail vehicles. Since there was no reason to assume a different operation emission factor for Luxembourgian rail vehicles, the 15 % value is adopted.

4.7.1.1.2 Foam blowing agents (2.F.2)

In spite of significant efforts to collect country-specific data, no improvement in the estimation of fluorinated greenhouse gas emissions related to foam blowing could be achieved. In fact, in the absence of a local producer, sales data are the most promising source of data but have remained unavailable by the end of the last re-assessment of emissions estimations. Waste treatment data, including an analysis of household garbage to search for erroneously disposed polyurethane (PU) cans, resulted in unrealistically low consumption figures for PU cans (approximately half the figures of the neighbouring countries). Therefore, as in the previous reports, the PU spray emissions (HFC 134a, HFC 152a) and the extruded polystyrene (XPS) emissions (HFC 134a) are estimated using the reported quantities used per habitant and year in Belgium, and their average HFC content, expressed per capita with the relative population in Luxembourg. Note that the Belgian data are all reported under closed-cell foam blowing emissions.

4.7.1.1.3 1.8.1.1.Fire extinguisher (2.F.3)

This source category does not exist in Luxembourg.

4.7.1.1.4 Aerosols (2.F.4)

Metered Dose Inhalers (MDI)

Emissions from MDIs were estimated on the basis of country specific data provided by IMS Health for the years 2001 to 2005, indicating the number of doses sold in Luxembourgian pharmacies. The share of doses sold in hospitals was assumed to amount to 5 %, in line with Belgian hospital sales. It was furthermore assumed that R134a was the only fluorinated greenhouse gas used in MDIs sold in Luxembourg, and that each dose contained 75 mg of R134a. For the years before 2001, a gradual ingression of R134a-using MDIs, from the first appearance in 1996 onwards, was assumed, in line with the German MDI evolution (Schwarz 2005). In order to estimate the total number of MDIs sold before 2001 and after 2005 (the period covered by IMS Health data), per capita MDI dose sales for 2001 and 2005 were extrapolated to the pre-2001 and the post-2005 years respectively on the basis of the population evolution. This approach admittedly neglected possible effects of dry powder injection (DPI) as an alternative to MDIs, and of population-independent variations in the number of asthmatic patients. In the absence of robust evidence, however, these factors could not be accounted for in the here-employed model.

In line with the 2006 IPCC reporting guidelines, emissions of MDIs sold in year x are assumed to be emitted at 50 % in the course of year x and at 50 % in the course of the following year x+1.

Other aerosols

No country-specific data on emissions from aerosols other than MDIs could be collected owing to the absence of aerosol manufacturing plants and the unavailability of importation data. As a result, the German per capita aerosol emissions were applied to Luxembourg.

4.7.1.1.5 Solvents (2.F.5)

This source category does not exist in Luxembourg.

4.7.1.2 Uncertainties and time-series consistency

The error values which are assumed on the various calculations are as given:

- Activity data uncertainty 30%
- Emission factor uncertainty 20%

4.7.1.3 Source-specific QA/QC and verification

The calculations of the data for category 3 are embedded in the overall QA/QC-system of the GHG inventory (see Chapter 1.6) of which important elements include:

- Are the correct values used (check for transcription errors, …)?
- Check of plausibility of input data (time-series, order of magnitude, …)
- Is the data set complete for the whole time series?
- Check of calculations, units ...
- Check of plausibility of results (time-series, order of magnitude, …)
- Correct transformation/transcription into CRF
- Where possible, data is checked with data from other sources, order of magnitude checks, …
- Are all references clearly made?

- Are all assumptions documented?

4.7.1.4 Category-specific recalculations including changes made in response to the review process

Regarding refrigerated transport of 2F1, the entire time series has been revised. In the previous approach, only newly registered refrigerated vehicles were considered for the yearly estimations of emissions. As such, emissions corresponding to the total amount of refrigerants in operating systems were incorrect. To comply with the 2006 IPCC Guidelines, emission estimates have been revised for the entire time series, and are now taking into account emissions from the entire fleet of refrigerated vehicles. Furthermore, regarding 2F1 - Stationary refrigeration and air conditioning, the completeness of the database has been revised for the year 2014, as such the emission data has been updated accordingly.

2F2 Foam blowing: The PU spray emissions (HFC 134a, HFC 152a) and the extruded polystyrene (XPS) emissions (HFC 134a) are estimated using the reported quantities used per habitant and year in Belgium, which have been updated. The data for Luxembourg for the years 2009-2014 has been revised accordingly.

2F4 Aerosols/Metered dose inhalers: data for 2013 and 2014 were incorrect and have been replaced by correct values.

4.7.1.5 Category-specific planned improvements including those in response to the review process

The following improvements to category *2F - Product uses as substitutes for ODS* are planned, or will be explored for the next submission depending on the availability of data and resources Table 4-33.

Table 4-33 – Planned improvements for IPCC Category 2F – Product uses as substitutes for ODS

GHG source & sink category	Planned improvement	Recommendation
2F2 – Foam blowing	continue the quest for country-specific data	
2F4 – Aerosols	continue the quest for country-specific data	

4.8 Other product manufacture and use (2.G)

4.8.1 Source category description

This section describes the estimation of F-gas emissions resulting from the category *2.G - Other product manufacture and use* from industrial processes (production, consumption). In 2015, the category 2.G represented 2.29% of the GHG emissions in CO_2e from industrial processes and 0.15% of the total GHG emissions in CO_2e (excluding LULUCF). This percentage was 0.09% in 1995. As shown in Figure 4-13, F-gases related emissions experienced an increase of 61% between 1995 and 2015. Compared to 2014, emissions increased by 4.74% to attain the level of 13.93 Gg CO_2 in 2015.

F-gas emission estimates are presented in Table 4-34.

Figure 4-13 GHG emission trends for CRF Sector 2G : 1990-2015

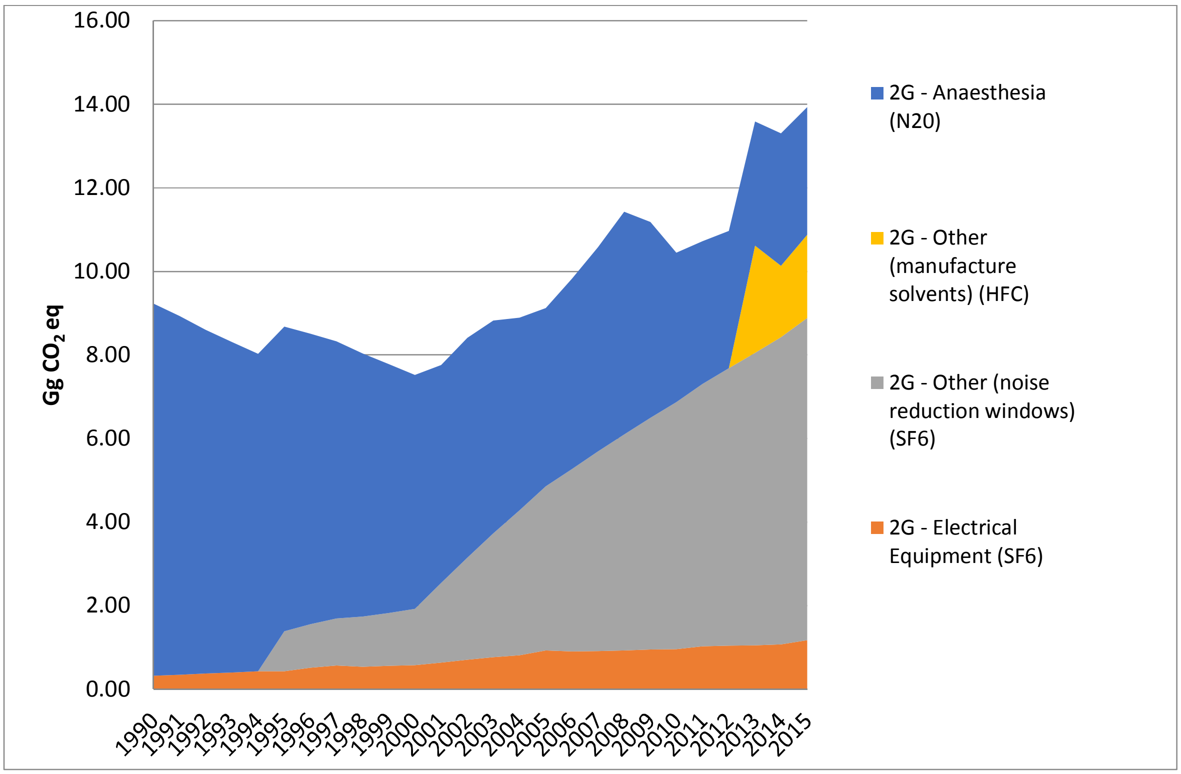


Table 4-34 Estimated emissions for CRF Sector 2F : 1990-2015

Year	2G - Other product manufacture and use	2G - Electrical Equipment (SF6)	2G - Other (noise reduction windows) (SF6)	2G - Other (manufacture solvents) (HFC)	2G - Anaesthesia (N_20)	2G - Propellant for pressure and aerosol products (N_20)
	Gg CO_2 e					
1990	9.23289	0.32674	NO	NO	8.90521	0.00094
1991	8.92992	0.34959	NO	NO	8.57938	0.00095
1992	8.60418	0.37386	NO	NO	8.22935	0.00097
1993	8.31110	0.39985	NO	NO	7.91027	0.00098
1994	8.03054	0.42770	NO	NO	7.60185	0.00099
1995	8.67489	0.43270	0.95677	NO	7.28442	0.00101
1996	8.51334	0.51693	1.04069	NO	6.95469	0.00102
1997	8.32492	0.57227	1.12486	NO	6.62676	0.00103
1998	8.03758	0.54137	1.19964	NO	6.29552	0.00105
1999	7.78133	0.55880	1.26745	NO	5.95401	0.00106
2000	7.52163	0.57696	1.34875	NO	5.59484	0.00108
2001	7.76145	0.64117	1.90311	NO	5.21608	0.00109
2002	8.41067	0.70499	2.44418	NO	5.26041	0.00110
2003	8.82478	0.76747	2.96457	NO	5.09163	0.00111
2004	8.89033	0.81738	3.46503	NO	4.60678	0.00113
2005	9.12149	0.92638	3.92689	NO	4.26706	0.00115
2006	9.83018	0.90764	4.36227	NO	4.55910	0.00117
2007	10.57804	0.91493	4.77710	NO	4.88482	0.00119
2008	11.42801	0.92546	5.17102	NO	5.33033	0.00121
2009	11.18454	0.95066	5.54422	NO	4.68843	0.00123
2010	10.45113	0.95691	5.91369	NO	3.57928	0.00125
2011	10.72370	1.02907	6.27946	NO	3.41389	0.00128
2012	10.96586	1.04139	6.64158	NO	3.28158	0.00131
2013	13.58844	1.05091	7.00007	2.56332	2.97285	0.00129
2014	13.30234	1.07354	7.35498	1.70560	3.16685	0.00137
2015	13.93303	1.17747	7.70781	1.98768	3.05867	0.00140
Trend 1995-2015	*61%*	*172%*	*706%*	*NA*	*-58%*	*39%*
Trend 2014-2015	*4.74%*	*9.68%*	*4.80%*	*16.54%*	*-3.42%*	*2.34%*

4.8.1.1 Methodology

The emissions of fluorinated greenhouse gases in Luxembourg were thoroughly re-assessed in 2014 in order to assure compliance with the 2006 IPCC reporting guidelines, to streamline data acquisition and processing, to include previously neglected applications and sub-applications, and to increase transparency of emissions estimations.

Generally speaking, emissions estimations in Luxembourg are based on emission-factor approaches. Due to highly incomplete records of chemical sales data (Econotec consultants 2010, importers inquiry 2014), mass-balance approaches are mostly inapplicable. Emission factors are predominantly derived from regional to global estimates. In some cases, it was possible to calculate country-specific emission factors.

4.8.1.2 Uncertainties and time-series consistency

The error values which are assumed on the various calculations are as given:

- Activity data uncertainty 30%
- Emission factor uncertainty 20%

4.8.1.3 Source-specific QA/QC and verification

The calculations of the data for category 3 are embedded in the overall QA/QC-system of the GHG inventory (see Chapter 1.6) of which important elements include:

- Are the correct values used (check for transcription errors, …)?
- Check of plausibility of input data (time-series, order of magnitude, …)
- Is the data set complete for the whole time series?
- Check of calculations, units ...
- Check of plausibility of results (time-series, order of magnitude, …)
- Correct transformation/transcription into CRF
- Where possible, data is checked with data from other sources, order of magnitude checks, …
- Are all references clearly made?
- Are all assumptions documented?

4.8.1.4 Category-specific recalculations including changes made in response to the review process

No revisions and recalculations have been done since the last submission.

4.8.1.5 Category-specific planned improvements including those in response to the review process

No improvements are planned for category *2G – Other product manufacture and use*.

4.8.2 Electrical equipment (2.G.1)

One of the major applications of fluorinated greenhouse gases outside the ODS substitute sector (air conditioning and refrigeration, aerosols, etc.) is sulphur hexafluoride (SF6) used as insulator in electrical switchgears. There are different types of switchgear, in particular depending on the voltage (20 kV, 65 kV and 220 kV), with a high diversity of SF6 charges per device. In terms of emissions estimation modalities the switchgear can be divided into medium voltage (MV) and high voltage (HV) devices.

In Luxembourg, there is one main operator of electrical switchgear devices (Creos), covering an estimated 80 % of the equipment, and a few smaller operators, four of which provided data on their equipment. The data available cover all HV devices. In order to account for possibly unreported MV equipment, 2 % were added to the reported stock of SF6 MV equipment.

Individual charges typically vary between less than 1 kg of SF6 in MV devices to several 100 kg in HV equipment. Data on type-specific charges were provided by the equipment operators.

MV equipment is pre-filled in the manufacture plant, which is not occurring in Luxembourg since all MV devices are imported. HV equipment, in contrast, is filled on site which entails manufacture or initial emissions that are relevant for Luxembourg. Since no reports on the amounts of SF6 emitted during such operations are available, the figures provided by Schwarz (2005) documenting the evolution of on-site filling emissions of HV equipment in Germany from 1997 to 2002 were used to calculate initial emission factors for Luxembourg for the period in question. The initial emission factors of 1997 and 2002 are extended to the preceding and the following years respectively.

Operation emissions are not reported by the equipment operators, which is why, again, regionally derived factors in line with the 2006 IPCC reporting guidelines and the recommendations of the VDN, VIK, ZVEI and Solvay (2003) report are used. For the MV devices, an operation emission factor of 0,1 % is assumed. For the HV equipment, operation emissions vary depending on the year of manufacture: 0,9 % for devices installed before 1997, 0,8 % for devices installed between 1997 and 2003, and 0,5 % for those installed since 2004. No refilling is assumed to occur over the equipment lifetime.

Emissions at decommissioning are assumed to be relevant only for the HV equipment, and are assumed to amount for 2 % of the initial charge (2006 IPCC reporting guidelines, Schwarz 2005).

4.8.3 SF6 and HFCs from other product use (2.G.2)

<u>*Noise reduction windows*</u>

A life-cycle approach is applied:

$$Emissions = EF \bullet AR + D$$

The activity rate (*AR*) is the calculated SF_6 stock on the basis of the estimated installed noise reduction windows, based on imported double glassed windows into Luxembourg with noise reduction fraction from Germany. The annual leakage rate of SF_6 is assumed to be 1% (EF=1%) and the lifespan 25 years. Disposal emissions (D) of the remaining SF_6 stock occur after a lifetime of 25 years. The resulting emissions in 2015 are 7.71 Gg CO_2-eq.

4.8.4 N_2O from product uses (2.G.3)

4.8.4.1 Medical applications (2.G.3.a)

N_2O emissions from Anaesthesia

In 2015, 0.07% of total GHG emissions (excluding LULUCF) in Luxembourg originated from *2G3 - N_2O emissions from anaesthesia*, compared to 0.03% in 1990. Compared to 2014, N_2O emissions from anaesthesia decreased by 3.48% and by 65.66% compared to 1990.

It was assumed that all the N_2O used for anaesthesia is completely released to the atmosphere. Emissions are shown in Table 4-35 and Figure 4-14.

For the period 1990-2002, no data from the hospitals on the consumption of N_2O could be obtained. Hence, N_2O emissions from anaesthesia usage were estimated by combining reported emissions in Germany with the relative population in Luxembourg. From 2003 to 2015, the use of N_2O in hospitals for anaesthesia was directly obtained from the "Entente des hôpitaux luxembourgeois". Thus, country-specific data was used. The data obtained covers the use of N_2O for anaesthesia in all hospitals of Luxembourg. The revised data from Germany (CRF 2015) for N_2O use in anaesthesia have been implemented and taken into account for the comparison.

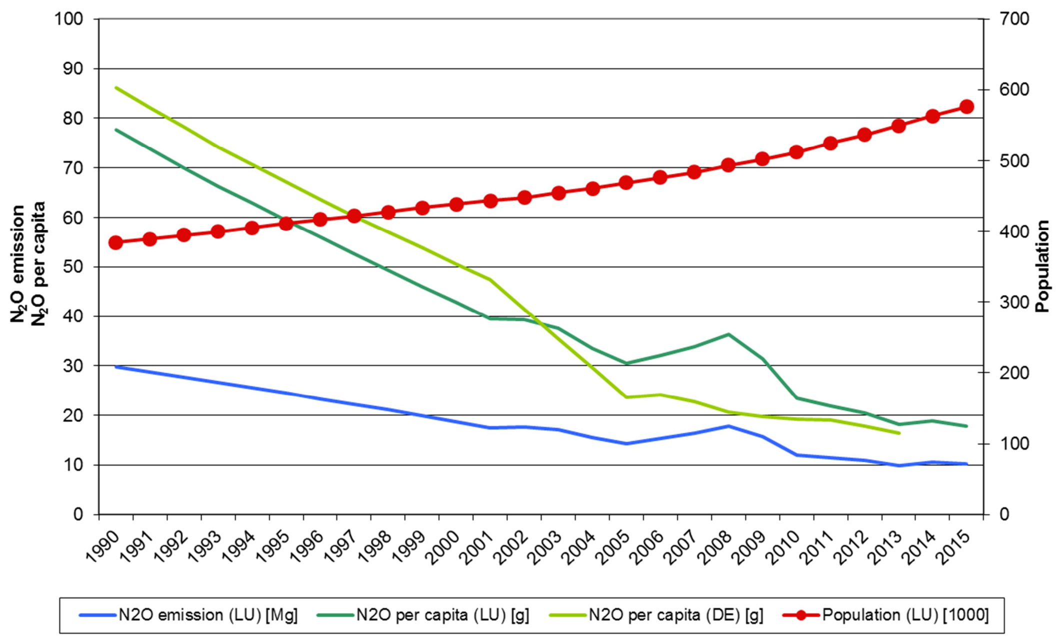
Although two different methods for the estimation of N_2O from anaesthesia are used over the time period (1990-2002 and 2003-2014), it is estimated that the time-series consistency is ensured. Indeed, when comparing the 2002 and 2003 values of emissions per capita of Germany with

Luxembourg's value, these are relatively similar (Table 4-35). From 2004 onwards, the German per capita emissions seem to decrease much more rapidly than Luxembourg's values thus avoiding a potential underestimation by applying a country-specific method. However, the general trend of decreasing emissions is consistent between the German and Luxembourgish figures thus ensuring time-series consistency. As such, direct comparison between German and Luxembourgish figures are only carried out until 2013.

Table 4-35 – 2.G.3.a - Use of N_2O for Anaesthesia: 1990–2015.

	Luxembourg			Germany
	N_2O emission (LU) [Mg]	Population (LU) [1000]	N_2O per capita (LU) [g]	N_2O per capita (DE) [g]
1990	29.88	384.4	77.74	86.07
1991	28.79	389.6	73.90	82.03
1992	27.62	394.8	69.95	78.17
1993	26.54	400.2	66.33	74.19
1994	25.51	405.7	62.88	70.58
1995	24.44	411.6	59.39	67.12
1996	23.34	416.9	55.98	63.68
1997	22.24	422.1	52.68	60.32
1998	21.13	427.4	49.43	57.07
1999	19.98	433.6	46.08	53.86
2000	18.77	439.0	42.77	50.55
2001	17.50	444.0	39.42	47.48
2002	17.65	448.3	39.38	41.45
2003	17.09	455.0	37.55	35.47
2004	15.46	461.2	33.52	29.55
2005	14.32	469.1	30.52	23.62
2006	15.30	476.2	32.13	24.17
2007	16.39	483.8	33.88	22.73
2008	17.89	493.5	36.25	20.69
2009	15.73	502.1	31.33	19.71
2010	12.01	511.8	23.47	19.15
2011	11.46	524.9	21.83	19.07
2012	11.01	537.0	20.51	17.83
2013	9.98	549.7	18.15	16.49
2014	10.63	563.0	18.88	/
2015	10.26	576.2	17.81	/

Figure 4-14 – N_2O emissions and N_2O consumption for anaesthesia per capita and trend: 1990–2015



4.8.4.1.1 Uncertainties and time-series consistency

Direct use of N_2O has been specifically collected from the hospitals in Luxembourg. According to WINIWARTER (2008) pursuant to RAMIREZ *ET AL.* 2006, an uncertainty of 20% for the amount of N_2O is used Table 4-36. In contrast to Ramirez, it is assumed that virtually all of the N_2O actually used is also fully released, thus no additional uncertainty is applied.

Table 4-36 - Uncertainties for category 2.G.3.a - N_2O emissions from anaesthesia.

IPCC Source category	Gas	AD	EF	Combined
			Uncertainty [%]	
2G3a - N_2O emissions from anaesthesia	N_2O	20.0	0	20.0

4.8.4.1.2 Source specific QA/QC and verification

The calculations of the data for category 3 are embedded in the overall QA/QC-system of the GHG inventory (see Chapter 1.6) of which important elements include:

- Are the correct values used (check for transcription errors, …)?
- Check of plausibility of input data (time-series, order of magnitude, …)
- Is the data set complete for the whole time series?
- Check of calculations, units ...
- Check of plausibility of results (time-series, order of magnitude, …)
- Correct transformation/transcription into CRF

- Where possible, data is checked with data from other sources, order of magnitude checks, …
- Are all references clearly made?
- Are all assumptions documented?

4.8.4.1.3 Category-specific recalculations including changes made in response to the review process

For the years 2013 and 2014, actual data was obtained regarding N_2O emissions. As such extrapolated data for 2013 and 2014 was replaced by the actual data.

4.8.4.1.4 Category-specific planned improvements including those in response to the review process

There are no planned improvements to IPCC sub-category 2.G.3.a.

4.8.4.2 Other (2.G.3.b)

Propellant for pressure and aerosol products

For the period 1990-2015, no data regarding exclusively the consumption of food aerosol cans, and the related N2O emission in Luxembourg, could be obtained. Hence, N2O emissions from propellant for pressure and aerosol products usage were estimated by combining reported emissions in Belgium with the relative population in Luxembourg. In 2015, 1,8E-08% of total GHG emissions (excluding LULUCF) in Luxembourg originated from 2.G.3.b - Propellant for pressure and aerosol products compared to 2,2E-08% in 1990. Compared to 2014, N2O emissions from Propellant for pressure and aerosol products increased by 2.34% and by 49.18% compared to 1990 (Table 4-37).

Table 4-37- 2.G.3.b - Use of N2O for Propellant for pressure and aerosol products: 1990–2015.

1.8.4.2 Other (2.G.3.b) Propellant for pressure and aerosol products		
	N_2O emission [Gg]	Population (LU) [1000]
1990	0.000942	384.4
1991	0.000954	389.6
1992	0.000967	394.8
1993	0.000980	400.2
1994	0.000994	405.7
1995	0.001008	411.6
1996	0.001021	416.9
1997	0.001034	422.1
1998	0.001047	427.4
1999	0.001062	433.6
2000	0.001075	439.0
2001	0.001088	444.0
2002	0.001098	448.3
2003	0.001115	455.0
2004	0.001130	461.2
2005	0.001149	469.1
2006	0.001167	476.2
2007	0.001185	483.8
2008	0.001209	493.5
2009	0.001230	502.1
2010	0.001254	511.8
2011	0.001280	524.9
2012	0.001309	537.0
2013	0.001287	549.7
2014	0.001373	563.0
2015	0.001405	576.2

4.8.4.2.1 Uncertainties and time-series consistency

The error values which are assumed on the various calculations are as given:

- Activity data uncertainty 30%
- Emission factor uncertainty 20%

4.8.4.2.2 Source specific QA/QC and verification

The calculations of the data for category 3 are embedded in the overall QA/QC-system of the GHG inventory (see Chapter 1.6) of which important elements include:

- Are the correct values used (check for transcription errors, …)?
- Check of plausibility of input data (time-series, order of magnitude, …)

- Is the data set complete for the whole time series?
- Check of calculations, units ...
- Check of plausibility of results (time-series, order of magnitude, …)
- Correct transformation/transcription into CRF
- Where possible, data is checked with data from other sources, order of magnitude checks, …
- Are all references clearly made?
- Are all assumptions documented?

4.8.4.2.3 Category-specific recalculations including changes made in response to the review process

No revisions and recalculations have been done since the last submission.

4.8.4.2.4 Category-specific planned improvements including those in response to the review process

There are no planned improvements to IPCC sub-category 2.G.3.b

4.8.4.3 Other (2.G.4)

In Luxembourg, one manufacturer is producing solvents belonging to the category 2.G.4. The aforementioned production started in 2013. Activity data is directly obtained from the manufacturer. The data is limited to the one manufacturer and is considered confidential, thus the here described information is restricted to the activity data. Uncertainties and time-series consistency.

4.8.4.3.1 Uncertainties and time-series consistency

The error values which are assumed on the various calculations are as given:

- Activity data uncertainty 30%
- Emission factor uncertainty 20%

4.8.4.3.2 Source specific QA/QC and verification

The calculations of the data for category 3 are embedded in the overall QA/QC-system of the GHG inventory (see Chapter 1.6) of which important elements include:

- Are the correct values used (check for transcription errors, …)?
- Check of plausibility of input data (time-series, order of magnitude, …)
- Is the data set complete for the whole time series?
- Check of calculations, units ...
- Check of plausibility of results (time-series, order of magnitude, …)
- Correct transformation/transcription into CRF
- Where possible, data is checked with data from other sources, order of magnitude checks, …
- Are all references clearly made?
- Are all assumptions documented?

4.8.4.3.3 Category-specific recalculations including changes made in response to the review process

No revisions and recalculations have been done since the last submission.

4.8.4.3.4 Category-specific planned improvements including those in response to the review process

There are no planned improvements to IPCC sub-category 2.G.4

4.9 Other (2.H)

This source category does not exist in Luxembourg.

5 Agriculture (CRF Sector 3)

5.1 Sector Overview

Chapter 6 includes information on and description of methodologies used for estimating GHG emissions as well as references to activity data and emission factors reported under CRF Sector 3 – Agriculture for the period 1990 to 2015.

Emissions from this sector comprise emissions from the following categories: enteric fermentation (3A), manure management (3B) and agricultural soils (3D and 3G). For more details on categories where emissions are not occurring and categories that are not estimated or included elsewhere, see Table 6-3 below.

The country of Luxembourg is lying in a cool climate region. Other required information will be presented under each source category review (methodology, AD, EFs, etc.).

5.1.1 Emission Trends

This section briefly describes the emission trends from 1990 to 2015 for each of the IPCC Categories under CRF Sector 3 for which GHG emissions are reported – i.e. categories 3A, 3B, 3D and 3G.

As shown in Table 6-1, emissions of GHG related to agricultural activities have decreased by about 5.57% (+1.7% for methane and -19.05% for nitrous oxide). IPCC Category 3A – Enteric Fermentation saw its emissions falling by 1.02%, whereas for IPCC category 3D – Agricultural Soils, the decrease reaches 17.62%. For manure management (IPCC Category 3B), emissions rose by 12.19% between 1990 and 2015, though opposite variations are observed for the two GHG emitted by this activity: methane increased by 23.51% and nitrous oxide declined by 10.16%.

Table 5-1 provides a quick overview on agriculture related emission trends between 1990 and 2015. More details and explanations are presented in the subsequent sections detailing each of the sector source categories.

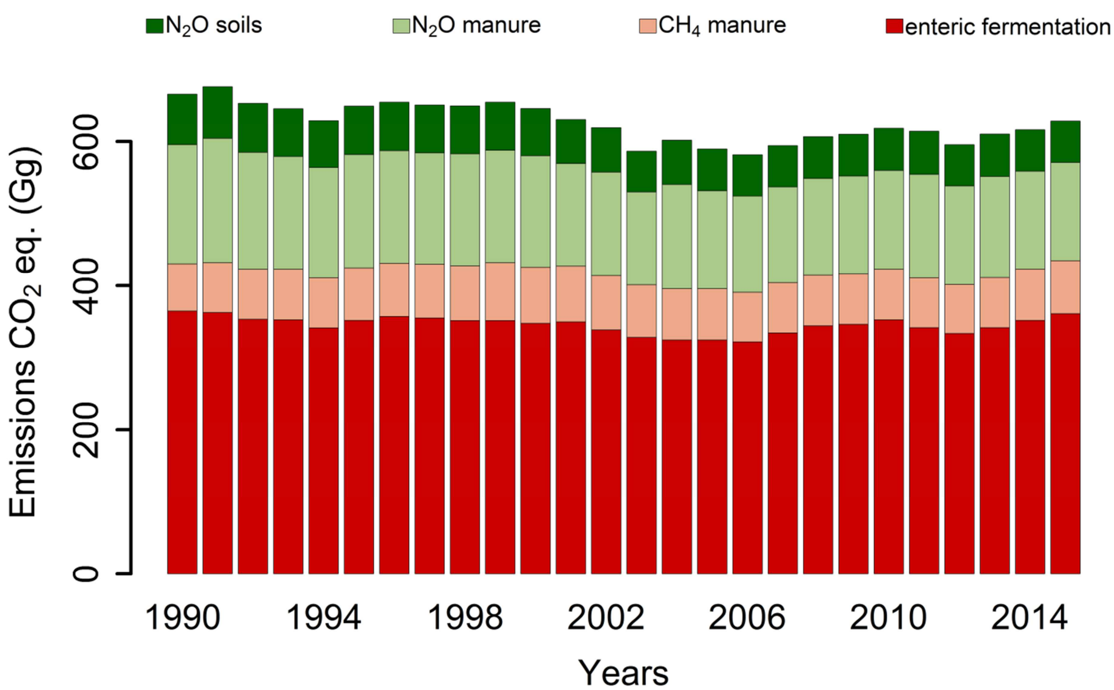
Table 5-1– GHG emission trends in Gg CO2 eq. for CRF Sector 3 – Agriculture: 1990-2015

	Enteric Fermentation				Manure management				Agricultural soils				Agriculture			
years	Total	CO2	CH4	N2O	Total	CO2	CH4	N2O	Total	CO2	CH4	N2O	Total	CO2	CH4	N2O
1990	364,588	NA	363,819	NA	65,778	NA	43,658	22,120	235,523	0,590	NA	234,9336	665,889	0,590	407,477	257,053
1991	362,447	NA	361,631	NA	69,436	NA	47,694	21,742	244,465	0,708	NA	243,7567	676,349	0,708	409,326	265,498
1992	353,268	NA	352,537	NA	69,665	NA	48,427	21,238	230,276	0,827	NA	229,4486	653,209	0,827	400,964	250,687
1993	352,396	NA	351,680	NA	70,345	NA	49,235	21,110	222,976	0,946	NA	222,0295	645,716	0,946	400,915	243,140
1994	341,322	NA	340,504	NA	69,339	NA	48,706	20,634	218,520	1,373	NA	217,1472	629,181	1,373	389,210	237,781
1995	351,704	NA	350,906	NA	73,033	NA	50,983	22,049	224,632	1,122	NA	223,51	649,369	1,122	401,889	245,559
1996	357,226	NA	356,470	NA	73,804	NA	51,457	22,347	223,757	0,990	NA	222,767	654,787	0,990	407,927	245,114
1997	355,122	NA	354,276	NA	74,818	NA	52,594	22,224	220,999	1,465	NA	219,5335	650,939	1,465	406,870	241,758
1998	351,524	NA	350,654	NA	75,919	NA	53,826	22,094	222,218	2,022	NA	220,1962	649,661	2,022	404,479	242,290
1999	351,372	NA	350,504	NA	80,512	NA	58,482	22,030	223,023	1,126	NA	221,897	654,908	1,126	408,986	243,927
2000	347,538	NA	346,696	NA	78,111	NA	56,730	21,381	220,647	1,888	NA	218,7593	646,296	1,888	403,426	240,140
2001	349,747	NA	348,851	NA	77,378	NA	56,166	21,211	204,089	2,288	NA	201,8012	631,214	2,288	405,018	223,013
2002	338,641	NA	337,679	NA	74,878	NA	54,633	20,245	205,665	2,904	NA	202,761	619,184	2,904	392,312	223,006
2003	328,212	NA	327,214	NA	72,718	NA	52,613	20,105	186,053	2,816	NA	183,2373	586,983	2,816	379,827	203,343
2004	324,539	NA	323,510	NA	71,050	NA	51,463	19,587	206,550	2,420	NA	204,1296	602,139	2,420	374,972	223,717
2005	324,653	NA	323,567	NA	70,928	NA	51,425	19,503	194,665	3,907	NA	190,7574	590,245	3,907	374,992	210,261
2006	322,006	NA	320,988	NA	68,629	NA	49,722	18,907	191,690	3,049	NA	188,6404	582,325	3,049	370,709	207,547
2007	334,425	NA	333,439	NA	69,540	NA	50,310	19,229	190,774	3,080	NA	187,6938	594,739	3,080	383,749	206,923
2008	344,215	NA	343,319	NA	70,087	NA	50,454	19,633	192,932	2,860	NA	190,0723	607,234	2,860	393,773	209,705
2009	346,290	NA	345,357	NA	69,538	NA	50,002	19,536	194,809	4,074	NA	190,7345	610,637	4,074	395,359	210,270
2010	352,438	NA	351,478	NA	70,318	NA	50,622	19,696	196,117	4,180	NA	191,9368	618,873	4,180	402,100	211,633
2011	341,570	NA	340,624	NA	69,095	NA	50,020	19,074	204,092	4,884	NA	199,2076	614,756	4,884	390,644	218,282
2012	333,557	NA	332,690	NA	67,777	NA	49,133	18,643	194,961	5,060	NA	189,9007	596,295	5,060	381,823	208,544
2013	341,585	NA	340,679	NA	69,494	NA	50,185	19,309	199,733	5,808	NA	193,9253	610,812	5,808	390,864	213,234
2014	349,356	NA	349,356	NA	70,913	NA	51,218	19,695	201,476	5,808	NA	195,6681	621,745	5,808	400,574	215,363
2015	360,866	NA	360,866	NA	73,796	NA	53,924	19,873	193,286	5,808	NA	187,4782	627,948	5,808	414,789	207,351
Trend 90-15	**-1,02%**		**-1,02%**		**12,19%**		**23,51%**	**-10,16%**	**-17,62%**	**885,07%**		**-19,89%**	**-5,57%**	**885,07%**	**1,60%**	**-19,05%**

As depicted in Figure 5-1, for both the years 1990 and 2015, IPCC Category 3A is the biggest contributor to agriculture related emissions. It is also worth noting that the shares of each IPCC Category under CRF Sector 3 for which GHG emissions are reported have not changed much over the period.

The evolution of IPCC Category 3D also shapes the overall agriculture emission pattern. This is mainly explained by important changes in crops, as well as in N-fertilizer use, which showed a slack in 2003 and a peak in 2004. The lower N-fertilizer use in 2003 was the result of the drought that characterized that year's summer.

Figure 5-1 – IPCC Categories CRF Sector 3 – Emissions from Agriculture (CO2 eq.): 1990 - 2015



In order to facilitate and complement the explanations provided in Sections 6.2 to 6.8 below, it is highly recommended to explore the R-files that have been developed to calculate GHG emissions from the agriculture sector. These files show the detailed calculations and are indicating (activity) data sources, methods, formulas, parameters, coefficients and equations used to estimate CH_4 and N_2O emissions as well as all the related references.

5.1.2 Key sources

The methodology and results of the key source analysis are presented in Chapter 1. Table 6-2 presents the key source categories of IPCC Sector 3 – Agriculture.

Table 5-2 – Key sources of IPCC Sector 3 – Agriculture

3 - Agriculture *Key sources*							
IPCC Category	**Category Name**	**GHG**	**LA excl. LULUCF**	**LA incl. LULUCF**	**TA excl. LULUCF**	**TA incl. LULUCF**
3A	Enteric Fermentation	CH_4	90-15	90-92, 94, 96, 98-01, 06-15		
3B	Manure Management	CH_4	95-02			
3D1	Direct N_2O Emissions from Managed Soils	N_2O	90-15			

Source: Environment Agency

Notes: LA = Level Assessement (Tier 1) including respectively exluding LULUCF
TA = Trend Assessement 2015 (Tier 1) including respectively excluding LULUCF

5.1.3 Completeness

Table 5-3 gives an overview of the IPCC categories included under CRF Sector 3 and provides information on the status of emission estimates of all subcategories. Category 3G is listed as NE as CO_2 Emissions from limestone are estimated but data for use of dolomite, urea and C-fertilizers are not available.

Table 5-3 – Overview of subcategories of CRF Sector 3 – Agriculture: status of emission estimates for CO_2, CH_4 and N_2O

GHG source & sink category	Description	Status		
		CO_2	CH_4	N_2O
3A – option C	enteric fermentation – calves		X	
3A	enteric fermentation – young cattle		X	
3A	enteric fermentation – bulls		X	
3A	enteric fermentation – bulls > 2 years		X	
3A	enteric fermentation – dairy cows		X	
3A	enteric fermentation – suckler cows		X	
3A	enteric fermentation - pigs reproduction		X	
3A	enteric fermentation - fattening pigs		X	
3A	enteric fermentation - sheep		X	
3A	enteric fermentation - goats		X	
3A	enteric fermentation - horses (1)		X	
3A	enteric fermentation – chicken		NO	
3A	enteric fermentation - laying hens		NO	
3A	enteric fermentation – other poultry		NO	
3A	enteric fermentation - ostriches		NO	
3A	enteric fermentation - rabbits		NO	
3A	enteric fermentation – cervidae		X	
3B – option C	manure management – calves		X	X
3B	manure management – young cattle		X	X
3B	manure management - bulls		X	X
3B	manure management - bulls > 2 years		X	X
3B	manure management - dairy cows		X	X
3B	manure management - suckler cows		X	X
3B	manure management - pigs reproduction		X	X
3B	manure management - fattening pigs		X	X
3B	manure management – sheep		X	X
3B	manure management – goats		X	X
3B	manure management – horses (1)		X	X
3B	manure management – chicken		X	X
3B	manure management – laying hens		X	X
3B	manure management – other poultry		X	X
3B	manure management - ostriches		X	X
3B	manure management - rabbits		X	X
3B	manure management - cervidae		X	X
3B	manure management – liquid systems		X	X
3B	manure management – solid storage & dry lot		X	X
3B	manure management – digester		X	X
3B	manure management - pasture		X	X
3C	rice cultivation – irrigated		NO	
3C	rice cultivation – rainfed		NO	
3C	rice cultivation – deep water		NO	
3C	rice cultivation – other		NO	
3D	agricultural soils – direct emissions from managed soils			X
3D	agricultural soils – indirect emissions from managed soils			X
3E	prescribed burning of savannahs		NO	NO
3F	field burning of agricultural residues – cereals		NO	NO
3F	field burning of agricultural residues – pulses		NO	NO
3F	field burning of agricultural residues – tubers & roots		NO	NO
3F	field burning of agricultural residues – sugar cane		NO	NO
3F	field burning of agricultural residues – other		NO	NO
3G	emissions from liming	X		
3H	emissions from urea application	NE		
3I	emissions from other C-fertilisers	NO		
3J	other	NO		

Footnotes: (1) the number of mules & asses where recorded together with horses

5.2 Enteric Fermentation (IPCC Source Category 3.A)

This section describes the estimation of methane emissions resulting from enteric fermentation. In 2015, this source category was responsible for 86.99% of agricultural methane emissions and for 69.12% of the total methane emissions estimated for Luxembourg. It represented 57.46% of the total GHG emissions from the agriculture sector and 4% of the total GHG emissions in CO_2eq. (excluding LULUCF).

5.2.1 Key source

With 6.63% of the total GHG emissions in CO_2 eq., excluding LULUCF in 2015 (6.9% of the total GHG emissions in CO_2 eq., including LULUCF), methane emissions from cattle (IPCC Sub-category 3A) is a key source, whether LULUCF is included or excluded. It has been a key source in both cases without interruption since 1990.

Table 5-4 – Domestic livestock population and trends: 1990-2015

years	calves	young cattle	Bulls 1-2	bulls >2	dairy cows	suckler cows	pigs reprod	fattening pigs	sheep	goats	horses	chicken	laying hens	other poultry	ostriches	rabbits	cervidae
1990	59553	58618	12950	5442	58840	24607	10336	65127	7281	506	1722	34511	34510	2261	C	13475	283
1991	59254	60128	13615	5624	55604	25697	9759	56833	7726	568	1829	31780	31779	2060	C	13563	283
1992	56214	58832	12738	4728	55937	25005	9942	57895	6924	433	1835	30141	30140	1824	C	12016	283
1993	55747	57232	13689	4714	54496	24976	9749	62051	6775	510	1925	31722	31722	1621	C	8559	283
1994	58026	54489	14120	4247	53307	22579	9623	59231	7744	497	2123	30226	30225	1523	C	7738	283
1995	57582	56776	15262	4936	53366	23735	10171	62469	7552	387	2164	27809	27809	1800	C	7168	283
1996	59094	57675	16152	5064	53100	24646	9791	62703	7152	293	2198	30928	30927	1594	C	5885	283
1997	57000	55905	16702	5576	50959	26193	10217	66932	8009	360	2295	33147	33146	1937	C	7240	174
1998	55319	54391	17112	5270	50649	25999	9974	71418	8237	294	2342	34182	34182	1390	C	6773	284
1999	55384	53843	16624	4812	50210	26989	10000	75830	8220	263	2818	31031	31030	982	C	6132	333
2000	54806	53220	16446	4383	48607	27610	9081	71060	7971	297	3154	23035	48750	849	C	6638	383
2001	54331	53042	16706	4833	47837	28444	9461	69079	8476	311	3126	21578	62739	999	C	6542	339
2002	53723	49498	14990	4188	46936	27922	8842	70823	9104	1103	3117	24376	53592	958	C	6993	318
2003	51325	48141	14290	3820	44950	27148	8215	75925	9446	1878	3449	16256	63032	1010	C	6516	238
2004	50819	47562	13761	3571	43956	27056	8285	76326	9743	2010	3686	12572	60539	1082	C	6603	285
2005	49195	47170	14505	3432	43418	27515	8323	81824	10277	2203	4193	20344	63063	1122	C	6514	234
2006	49453	46807	13978	3169	42193	28040	7761	76390	9644	1950	4336	19269	61983	1153	C	6840	244
2007	52699	49170	14396	2803	42939	29921	7565	75690	9339	2814	4334	17459	64449	814	C	4792	175
2008	52055	47760	16495	3187	43585	32579	7355	74019	8477	2912	4536	8081	73294	632	C	4112	323
2009	52410	47710	15440	3817	44310	32783	7473	72744	8824	3130	4562	17325	80093	833	C	4144	334
2010	52244	48905	16488	3700	45008	32485	7589	76185	9084	5084	4601	17172	72409	543	C	3482	311
2011	52261	46951	14283	3183	44113	31744	6949	82209	8951	5821	4594	17451	84098	682	C	2768	407
2012	52502	46071	13136	2827	43436	30501	6259	83764	8211	4898	4887	17817	94981	1544	C	3593	356
2013	53252	46487	14371	3097	46195	30221	6262	81256	8582	4456	4682	15560	95748	853	C	3415	265
2014	53289	51051	15666	3521	46199	29054	5954	81138	8721	4322	4724	15400	100142	828	C	3022	271
2015	54059	52951	14198	3702	46903	29223	5426	89911	9453	4772	4717	18440	95287	960	C	2714	239
Trend 90 - 15	**-9%**	**-10%**	**10%**	**-32%**	**-20%**	**19%**	**-48%**	**38%**	**30%**	**843%**	**174%**	**-47%**	**176%**	**-58%**		**-80%**	**-16%**

Sources: SER – agricultural census.

Notes: a) mules & asses population are reported together with horses' population.

Table 5-5 – CH4 emission trends for IPCC Category 3A – Enteric Fermentation: 1990-2015 (Gg)

years	calves	young cattle	Bulls 1-2	bulls >2	dairy cows	suckler cows	pigs reprod	fattening pigs	sheep	goats	horses	chicken	laying hens	other poultry	ostriches	rabbits	cervidae	total
1990	2,211	3,704	1,027	0,405	7,051	2,740	0,016	0,098	0,035	0,003	0,031	NO	NO	NO	NO	NO	0,006	17,325
1991	2,200	3,799	1,080	0,419	6,676	2,869	0,015	0,085	0,037	0,003	0,033	NO	NO	NO	NO	NO	0,006	17,221
1992	2,087	3,718	1,010	0,352	6,653	2,792	0,015	0,087	0,033	0,002	0,033	NO	NO	NO	NO	NO	0,006	16,787
1993	2,069	3,616	1,086	0,351	6,646	2,796	0,015	0,093	0,032	0,003	0,035	NO	NO	NO	NO	NO	0,006	16,747
1994	2,154	3,443	1,120	0,316	6,474	2,521	0,014	0,089	0,037	0,002	0,038	NO	NO	NO	NO	NO	0,006	16,214
1995	2,138	3,588	1,211	0,367	6,561	2,655	0,015	0,094	0,036	0,002	0,039	NO	NO	NO	NO	NO	0,006	16,710
1996	2,194	3,644	1,281	0,377	6,527	2,762	0,015	0,094	0,034	0,001	0,040	NO	NO	NO	NO	NO	0,006	16,975
1997	2,116	3,533	1,325	0,415	6,349	2,933	0,015	0,100	0,038	0,002	0,041	NO	NO	NO	NO	NO	0,003	16,870
1998	2,054	3,437	1,357	0,392	6,334	2,913	0,015	0,107	0,039	0,001	0,042	NO	NO	NO	NO	NO	0,006	16,698
1999	2,056	3,402	1,319	0,358	6,311	3,018	0,015	0,114	0,039	0,001	0,051	NO	NO	NO	NO	NO	0,007	16,691
2000	2,034	3,363	1,304	0,326	6,171	3,087	0,014	0,107	0,038	0,001	0,057	NO	NO	NO	NO	NO	0,008	16,509
2001	2,017	3,352	1,325	0,360	6,159	3,177	0,014	0,104	0,040	0,002	0,056	NO	NO	NO	NO	NO	0,007	16,612
2002	1,994	3,128	1,189	0,312	6,106	3,120	0,013	0,106	0,043	0,006	0,056	NO	NO	NO	NO	NO	0,006	16,080
2003	1,905	3,042	1,133	0,284	5,933	3,036	0,012	0,114	0,045	0,009	0,062	NO	NO	NO	NO	NO	0,005	15,582
2004	1,886	3,005	1,091	0,266	5,875	3,026	0,012	0,114	0,046	0,010	0,066	NO	NO	NO	NO	NO	0,006	15,405
2005	1,826	2,981	1,151	0,255	5,844	3,076	0,012	0,123	0,049	0,011	0,075	NO	NO	NO	NO	NO	0,005	15,408
2006	1,836	2,958	1,109	0,236	5,745	3,137	0,012	0,115	0,046	0,010	0,078	NO	NO	NO	NO	NO	0,005	15,285
2007	1,956	3,107	1,142	0,209	5,854	3,345	0,011	0,114	0,044	0,014	0,078	NO	NO	NO	NO	NO	0,004	15,878
2008	1,932	3,018	1,308	0,237	5,942	3,645	0,011	0,111	0,040	0,015	0,082	NO	NO	NO	NO	NO	0,006	16,348
2009	1,946	3,015	1,225	0,284	6,046	3,664	0,011	0,109	0,042	0,016	0,082	NO	NO	NO	NO	NO	0,007	16,445
2010	1,939	3,090	1,308	0,275	6,210	3,630	0,011	0,114	0,043	0,025	0,083	NO	NO	NO	NO	NO	0,006	16,737
2011	1,940	2,967	1,133	0,237	6,104	3,543	0,010	0,123	0,043	0,029	0,083	NO	NO	NO	NO	NO	0,008	16,220
2012	1,949	2,911	1,042	0,210	6,030	3,406	0,009	0,126	0,039	0,024	0,088	NO	NO	NO	NO	NO	0,007	15,842
2013	1,977	2,937	1,140	0,231	6,284	3,371	0,009	0,122	0,041	0,022	0,084	NO	NO	NO	NO	NO	0,005	16,223
2014	1,978	3,226	1,124	0,262	6,364	3,235	0,009	0,122	0,085	0,022	0,085	NO	NO	NO	NO	NO	0,005	16,636
2015	2,007	3,346	1,126	0,276	6,824	3,257	0,008	0,135	0,093	0,024	0,085	NO	NO	NO	NO	NO	0,005	17,184
Trend 90 - 15	**-9,2%**	**-9,7%**	**9,6%**	**-32,0%**	**-3,2%**	**18,9%**	**-47,5%**	**38,1%**	**29,8%**	**843,1%**	**173,9%**						**-15,5%**	**-1,0%**

Source: SER.

5.2.2 Source category description

Table 5-4 identifies and describes the various animal categories that have been taken into account for estimating methane emissions from enteric fermentation. Livestock statistics in Luxembourg are detailed enough to go for option C. Cattle are subdivided into 6 categories, namely calves, young cattle, bulls, bulls older than 2 years, dairy cows and suckler cows. Swine have been split into breeding pigs and fattening pigs (including piglets), chicken into chicken and laying hens. Mules and asses are recorded together in the category horses. The remaining categories are sheep, goats, other poultry, ostriches, rabbits and cervidae.

Looking at animal species for which data are available for the whole period 1990-2015, goats have experienced the biggest increase in their population whereas rabbits show the biggest decline in population. As shown in Table 5-5, which recapitulates methane emissions from enteric fermentation for each of the livestock category, goats related methane emissions are low compared to emissions originating from dairy and suckler cows, the two main methane emitting animal categories with regard to enteric fermentation.

Figure 5-1 shows GHG emissions in CO_2 equivalent from enteric fermentation by the livestock population.

On the whole, methane emissions from enteric fermentation decreased by around 1% over the period 1990-2015. This was mainly the result from declining emissions generated by dairy cows, namely -3.2%. Increasing emissions were recorded for the other livestock categories with +173.9% for horses, +843.1% for goats and +38.1% for fattening pigs.

With regard to cattle, its total population and its evolution are strongly influenced by changes in agricultural policy and, more precisely, in the Common Agricultural Policy of the EU (*CAP*). This is the case for dairy cows, whose declining population results from the combination of increasing milk yields and the introduction of a milk production cap (administrative quota system for milk production). Foreseen changes in the CAP in the coming years might therefore produce remarkable changes in the cattle population that will be reported in future inventories. Another factor influencing cattle population is, of course, fodder and milk prices (which, themselves are affected by agricultural policy changes and targets). As an example, the peak in the non-dairy cattle population observed in 1991 can be explained by a sharp price fall of the bovine meat price that year. This price fall led farmers to postpone slaughtering until early 1992.

Even though dairy cattle population decreased by 20% between 1990 and 2015, related methane emissions only declined by 3.2%. This is explained by an increasing per capita milk yield over the period, which led to an increase of the gross energy intake for dairy cattle.

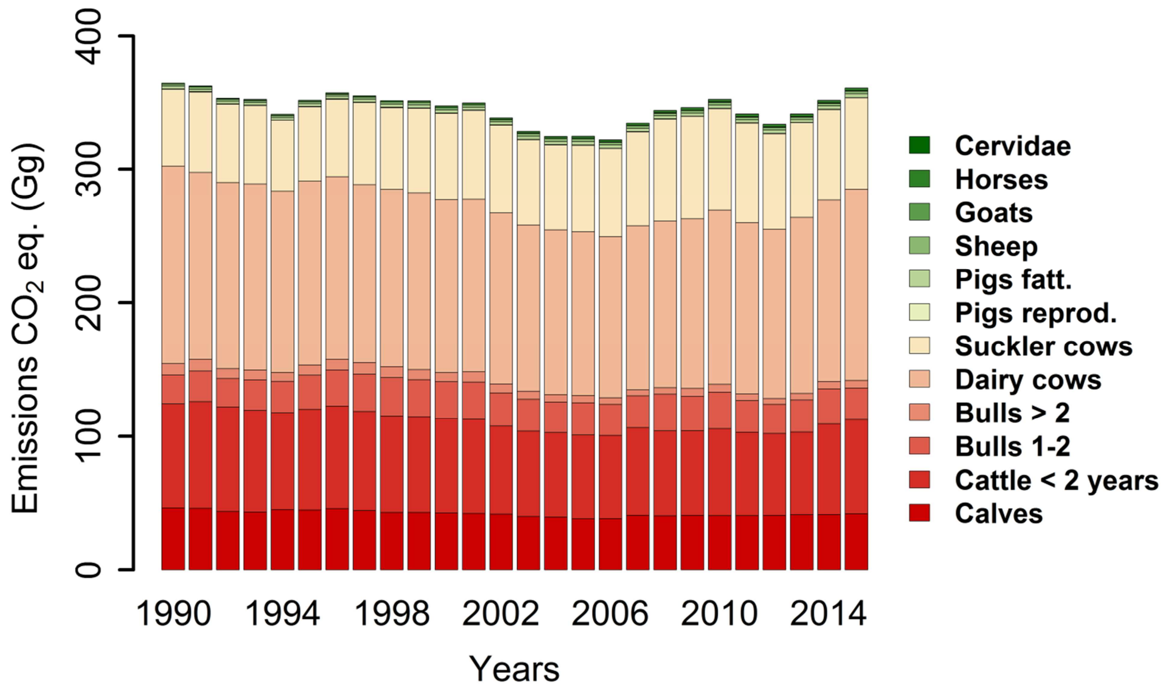


Figure 5-2 – Enteric fermentation per animal category: 1990 - 2015

5.2.3 Methodological issues

The IPCC Tier 2 method has been applied to all cattle categories and sheep. Tier 1 was used for pigs, goats, horses and cervidae.

5.2.3.1 Activity data

The following activity data have been extracted from national statistics:

- number of animals: see Table 5-4;
- milk production and the fat content of milk for dairy cattle: see Table 5-6.

5.2.3.1.1 Milk production and fat content

The milk production is the official amount of milk delivered by the producers. It is measured in t per year. The SER calculates the milk production by adding up:

- the amount of milk collected by the dairy industry directly from the farmers;
- the amount of milk and milk products directly sold by the farmers;
- milk consumption within the farms (for the farmer and its family, and for its animals).

The average milk yield is obtained by dividing the annual production by the number of dairy cows; suckler cows are estimated to give 3500 kg of milk per year on average. Over the period 1990-2015, the milk yield has increased by 23 %. This trend is likely to go on as the milk quota system came to an end by mid-2015. At the same time – see Table 5-4 above – the dairy cattle population declined by 20%. As these two parameters are the main drivers for the calculation of the IEF under the Tier 2 method, it is no surprise to record a 19% increase since 1990 for the IEF expressed in CH_4/head/year – see Table 5-11 in Section 5.2.3.2.3.

Table 5-6 – Milk production and fat content of milk for dairy cattle: 1990-2015

years	milk production (t/year)	milk fat content (%)
1990	281700	4,09
1991	265100	4,16
1992	260400	4,16
1993	268200	4,22
1994	261600	4,16
1995	268600	4,2
1996	265500	4,25
1997	263900	4,23
1998	264000	4,25
1999	266572	4,2
2000	264556	4,19
2001	269674	4,17
2002	270665	4,18
2003	267114	4,2
2004	268539	4,2
2005	269711	4,19
2006	268070	4,21
2007	274243	4,19
2008	277672	4,21
2009	283876	4,18
2010	295302	4,18
2011	292247	4,15
2012	289395	4,16
2013	295855	4,13
2014	317045	4,09
2015	346290	4,11
trend('90-'15)	**23%**	

Sources: SER.

5.2.3.1.2 Live-weight

Live-weights for most animal categories have been provided by SER. These data are not published as such and, therefore, might be considered as expert judgments. However, they rely on measurements and are not purely speculative. These weights are constant over time and are provided in Table 5-7.

Table 5-7 – Live-weight for farm animals reported in the inventory

Livestock category	Live-weight in kg	Comments
3B - enteric fermentation – calves	190	
3B - enteric fermentation – young cattle	450	
3B - enteric fermentation – bulls	480	
3B - enteric fermentation – bulls > 2 years	750	
3B - enteric fermentation – dairy cows	650	
3B - enteric fermentation – suckler cows	700	
3B - enteric fermentation - pigs reproduction	170	
3B - enteric fermentation - fattening pigs	80	
3B - enteric fermentation - sheep	45	
3B - enteric fermentation - goats	40	
3B - enteric fermentation - horses (1)	600	
3B - enteric fermentation – chicken	1	
3B - enteric fermentation - laying hens	1,2	
3B - enteric fermentation – other poultry	1,2	
3B - enteric fermentation - ostriches	120	
3B - enteric fermentation - rabbits	1,6	
3B - enteric fermentation – cervidae	60	

Source: SER.
Notes:
(1) mules & asses population are reported together with horses' population.

5.2.3.2 Emission factors

EFs for enteric fermentation related methane emissions are actually IEFs obtained by combining the average gross energy intake (*GE* in MJ per day) of each animal category with a methane conversion rate (*Ym* in %) provided in the IPCC Guidelines:

$$IEF_i = [GE_i \ x \ Ym_i \ x \ 365.242199] \ / \ 55.65$$

for each livestock category i

IEF_i expressed in kg CH_4/head/year

the factor 55.65 expressed in MJ/kg of CH_4

➔ see equation 10.21 of the 2006 IPCC GLs.

For the Tier 1 method, default GE is usually provided in the IPCC Guidelines. For the Tier 2 method, GE is the combination of various feed intake – or net energy – estimates relating to maintenance, activity, growth, etc. of the animals.

Table 5-8 indicates, for each animal category, which method has been used to estimate methane emissions as well as the corresponding IEF type.

Table 5-8 – Method and type of EF used in the inventory

Livestock category	Estimation method	IEF	Comments
3A - enteric fermentation – calves	T2	CS	
3A - enteric fermentation – young cattle	T2	CS	
3A - enteric fermentation – bulls	T2	CS	
3A - enteric fermentation – bulls > 2 years	T2	CS	
3A - enteric fermentation – dairy cows	T2	CS	
3A - enteric fermentation – suckler cows	T2	CS	
3A - enteric fermentation - pigs reproduction	T1	D	IPCC 2006 GLs
3A - enteric fermentation - fattening pigs	T1	D	IPCC 2006 GLs
3A - enteric fermentation - sheep	T2	CS	
3A - enteric fermentation - goats	T1	D	IPCC 2006 GLs
3A - enteric fermentation - horses (1)	T1	D	IPCC 2006 GLs
3A - enteric fermentation – chicken	NO	NO	No EF in EFDB
3A - enteric fermentation - laying hens	NO	NO	No EF in EFDB
3A - enteric fermentation – other poultry	NO	NO	No EF in EFDB
3A - enteric fermentation - ostriches	NO	NO	No EF in EFDB
3A - enteric fermentation - rabbits	NO	NO	No EF in EFDB
3A - enteric fermentation – cervidae	T1	D	IPCC 2006 GLs

Source: SER.
Abbreviations: T1 = Tier 1; T2 = Tier 2 ; CS = Country Specific ; D = IPCC Default .

5.2.3.2.1 Tier 2 method – cattle and sheep

For cattle and sheep, the IEF has been calculated by combining the following activity data, coefficients and parameters:

Table 5-9 – Activity data, coefficients and parameters used for IPCC Sub-category 3A1

AD, parameter, coefficient	Unit	Source(s)	Type of value
Livestock (# of heads)	#	SER	AD (see Table 6-4)
(Live) Weight	kg	SER	AD (see Table 6-7), invariable
Live Body Weight	kg	Revised 1996 IPCC Guidelines & 2006 IPCC GLs	calculated, invariable
Daily Weight Gain	kg/day	-	NA
Milk Yield	t/year	SER	AD (see Table 6-6)
Daily Milk Production	kg/cow/day	-	Calculated using 365. 242199 days/year
Fat Content of Milk	%	SER	AD (see Table 6-6)
Digestible Energy	%	based on table 10.2 - 2006 IPCC GLs	expert judgment, invariable
Net Energy for Maintenance	MJ/day	equation 10.3 - 2006 IPCC GLs	calculated using the default coefficient for lactating cattle, invariable
Net Energy for Activity	MJ/day	equation 10.4 +.5 - 2006 IPCC GLs	calculated using the default cattle coefficient for pasture, invariable
Net Energy for Growth	MJ/day	equation 10.6 + .7 - 2006 IPCC GLs	calculated, nil by definition
Net Energy for Lactation	MJ/day	equation 10.8 + .9 - 2006 IPCC GLs	calculated using daily milk production

AD, parameter, coefficient	Unit	Source(s)	Type of value
Net Energy for Work	MJ/day	equation 10.11 - 2006 IPCC GLs	NO
Net Energy for Wool	MJ/day	equation 10.12 - 2006 IPCC GLs	2.5 kg wool per year
Net Energy for Pregnancy	MJ/day	equation 10.13 - 2006 IPCC GLs	
Ratio of Net Energy in a Diet for Maintenance to Digestible Energy Consumed	#	equation 10.14 - 2006 IPCC GLs	calculated, invariable
Ratio of Net Energy Available for Growth in a Diet to Digestible Energy Consumed	#	equation 10.15 - 2006 IPCC GLs	calculated, invariable
Gross Energy Intake (average)	MJ/day	equation 10.16 - 2006 IPCC GLs	calculated
Dry Matter Intake	kg/day	equation 10.17, .18a + .18b - 2006 IPCC GLs	calculated
CH_4 Conversion Rate (average)	%	table 10.12 +.13 - 2006 IPCC GLs	default for developed countries

5.2.3.2.2 Tier 1 method – pigs, goats, horses and cervidae

For farm animals which are not cattle, the IEF is generally the default enteric fermentation EF for developed countries presented in Table 10.10 of the 2006 IPCC Guidelines. More details are provided in Table 5-10.

Table 5-10 – Activity data, coefficients and parameters used for IPCC Sub-categories 3A3 to 3A10

AD, parameter, coefficient	Unit	Source(s)	Type of value
Livestock (# of heads)	#	SER & STATEC	AD (see Table 6-4)
CH_4 emission factors	kg CH_4 /(head * year)	table 10.10 - 2006 IPCC GLs IPCC EFDB	default for developed countries
CH_4 emissions	Gg $CH_{4/year}$	equation 10.19 - 2006 IPCC GLs	

Notes:

a) if an animal category is not indicated, it means that the value is NE for that particular AD, parameter or coefficient.

5.2.3.2.3 Methane IEFs for 3.A – Enteric Fermentation

Table 5-11 presents the IEFs obtained for each farm animal category using the Tier 1 or Tier 2 methods described above.

Table 5-11 – CH_4 IEFs trends for IPCC Category 3A – Enteric Fermentation: 1990-2015 (kg CH_4 / animal)

years	calves	young cattle	Bulls 1-2	bulls >2	dairy cows	suckler cows	pigs reprod	fattening pigs	sheep	goats	horses	chicken	laying hens	other poultry	ostriches	rabbits	cervidae
1990	37,1	63,2	79,3	74,4	119,8	111,4	1,5	1,5	9,8	5,0	18,0	NE	NE	NE	NE	NE	20,0
1991	37,1	63,2	79,3	74,4	120,1	111,7	1,5	1,5	9,8	5,0	18,0	NE	NE	NE	NE	NE	20,0
1992	37,1	63,2	79,3	74,4	118,9	111,7	1,5	1,5	9,8	5,0	18,0	NE	NE	NE	NE	NE	20,0
1993	37,1	63,2	79,3	74,4	122,0	111,9	1,5	1,5	9,8	5,0	18,0	NE	NE	NE	NE	NE	20,0
1994	37,1	63,2	79,3	74,4	121,4	111,7	1,5	1,5	9,8	5,0	18,0	NE	NE	NE	NE	NE	20,0
1995	37,1	63,2	79,3	74,4	122,9	111,8	1,5	1,5	9,8	5,0	18,0	NE	NE	NE	NE	NE	20,0
1996	37,1	63,2	79,3	74,4	122,9	112,1	1,5	1,5	9,8	5,0	18,0	NE	NE	NE	NE	NE	20,0
1997	37,1	63,2	79,3	74,4	124,6	112,0	1,5	1,5	9,8	5,0	18,0	NE	NE	NE	NE	NE	20,0
1998	37,1	63,2	79,3	74,4	125,1	112,1	1,5	1,5	9,8	5,0	18,0	NE	NE	NE	NE	NE	20,0
1999	37,1	63,2	79,3	74,4	125,7	111,8	1,5	1,5	9,8	5,0	18,0	NE	NE	NE	NE	NE	20,0
2000	37,1	63,2	79,3	74,4	126,9	111,8	1,5	1,5	9,8	5,0	18,0	NE	NE	NE	NE	NE	20,0
2001	37,1	63,2	79,3	74,4	128,7	111,7	1,5	1,5	9,8	5,0	18,0	NE	NE	NE	NE	NE	20,0
2002	37,1	63,2	79,3	74,4	130,1	111,8	1,5	1,5	9,8	5,0	18,0	NE	NE	NE	NE	NE	20,0
2003	37,1	63,2	79,3	74,4	132,0	111,8	1,5	1,5	9,8	5,0	18,0	NE	NE	NE	NE	NE	20,0
2004	37,1	63,2	79,3	74,4	133,7	111,8	1,5	1,5	9,8	5,0	18,0	NE	NE	NE	NE	NE	20,0
2005	37,1	63,2	79,3	74,4	134,6	111,8	1,5	1,5	9,8	5,0	18,0	NE	NE	NE	NE	NE	20,0
2006	37,1	63,2	79,3	74,4	136,2	111,9	1,5	1,5	9,8	5,0	18,0	NE	NE	NE	NE	NE	20,0
2007	37,1	63,2	79,3	74,4	136,3	111,8	1,5	1,5	9,8	5,0	18,0	NE	NE	NE	NE	NE	20,0
2008	37,1	63,2	79,3	74,4	136,3	111,9	1,5	1,5	9,8	5,0	18,0	NE	NE	NE	NE	NE	20,0
2009	37,1	63,2	79,3	74,4	136,4	111,8	1,5	1,5	9,8	5,0	18,0	NE	NE	NE	NE	NE	20,0
2010	37,1	63,2	79,3	74,4	138,0	111,8	1,5	1,5	9,8	5,0	18,0	NE	NE	NE	NE	NE	20,0
2011	37,1	63,2	79,3	74,4	138,4	111,6	1,5	1,5	9,8	5,0	18,0	NE	NE	NE	NE	NE	20,0
2012	37,1	63,2	79,3	74,4	138,8	111,7	1,5	1,5	9,8	5,0	18,0	NE	NE	NE	NE	NE	20,0
2013	37,1	63,2	79,3	74,4	136,0	111,5	1,5	1,5	9,8	5,0	18,0	NE	NE	NE	NE	NE	20,0
2014	37,1	63,2	79,3	74,4	137,7	111,3	1,5	1,5	9,8	5,0	18,0	NE	NE	NE	NE	NE	20,0
2015	37,1	63,2	79,3	74,4	145,5	111,4	1,5	1,5	9,8	5,0	18,0	NE	NE	NE	NE	NE	20,0
trend ('90 -'13)	0%	0%	0%	0%	19%	0%	0%	0%	0%	0%	0%						0%

Source: SER.

Notes: a) mules & asses are recorded together with horses.

5.2.4 Category-specific recalculations including changes made in response to the review process

No recalculations were made.

5.2.5 Category specific uncertainty

Animal numbers' uncertainty is estimated to be 0.2%. For emission factors, uncertainties for enteric fermentation CH_4 emissions are estimated 30% for all animals. Table 5-12 gives an overview of uncertainties used to determine total uncertainties per GHG which is represented in Table 5-37.

Table 5-12 - Used uncertainties used in category 3A

Category	Description	Uncertainty	Source
EF ef	emission factor enteric fermentation	30%	see 10.3.4 p 10.33
Animal data	activity data on animal population	0,2%	estimation by sector expert
Ym	methane conversion factor	1%	Tab 10.12 + 13
gross energy	gross energy intake	20%	see 10.2.3 p 10.23

5.2.6 Category-specific QA/QC and verification

Consistency and completeness checks have been performed directly while calculating GHG emissions from the agriculture sector as well as by using the tools embedded in CRF Reporter.

The plausibility of the estimates, as well as the calculation methods, were discussed and developed by the sector experts, SER and ASTA. Category-specific checklists have also been filled in and cross-checked with the NIC and the QA/QC manager SEG-Umwelt Service Gmbh (see section of this NIR).

5.2.7 Planned improvement

No improvement is planned, as all possible improvements took place while establishing the GHG inventory for the agricultural sector according to 2006 IPCC Guidelines. Should emission factors for animal categories for which no emissions are estimated in this inventory be developed and recognised by the IPCC, they will be introduced into the calculating system and the reporting will be updated.

5.3 Manure Management (IPCC Source Category 3.B)

This section describes the estimation of methane and nitrous oxide emissions resulting from manure management. In 2015, this source category was responsible for 11.75% of the total GHG emissions from the agriculture sector and represented 1% of the total GHG emissions in CO_2e (excluding LULUCF). For each of the two gases reported, excluding LULUCF, in 2015:

- CH_4 represented 13% of agricultural methane emissions and 10.3% of the total methane emissions estimated for Luxembourg;
- N_2O represented 9.5% of agricultural nitrous oxide emissions and 12.6% of the total nitrous oxide emissions estimated for Luxembourg.

5.3.1 Key source

With 0.97% of the total GHG emissions in CO_2e, excluding LULUCF in 2015 (1.01% of the total GHG emissions in CO_2e, including LULUCF), methane emissions from manure management (IPCC Sub-category 3B) were a key source from 1995 to 2002 when LULUCF is excluded.

5.3.2 Source category description

Table 5-4 in Section 5.2.1 identifies and describes the various animal categories that have been taken into account for estimating methane and nitrous oxide emissions from manure management. The farm animal population recorded for estimating manure related emissions is identical to the population reported for enteric fermentation. Consequently, here too, livestock statistics are detailed enough to go for option C.

Looking at methane emissions from manure management - Table 5-13 – an increase of 23.5% can be observed for the period 1990-2015. Animals who did contribute the most of these emissions are cattle. For the other farm animal categories, methane emissions can be considered as negligible.

Looking at nitrous oxide emissions from manure management –Table 5-14 – a decrease of 10.2% is observed for the period 1990-2015. These emissions are mainly due to cattle. CRF requires reporting emissions by AWMS categories rather than by livestock categories. As shown in Table 5-15, solid storage is the main source of N_2O.

Combining both gases – CH_4 and N_2O – manure management related emissions, expressed in CO_2e, show an increase of 12% – Table 5-16.

Table 5-13 – CH4 emission trends for IPCC Category 3B – Manure Management: 1990-2015 (Gg)

years	calves	young cattle	Bulls 1-2	bulls >2	dairy cows	suckler cows	pigs reprod	fattening pigs	sheep	goats	horses	chicken	laying hens	other poultry	ostriches	rabbits	cervidae	total
1990	0,173	0,281	0,087	0,034	0,855	0,208	0,085	0,350	0,002	0,000	0,003	0,000	0,001	0,000	NO	0,001	0,000	2,079
1991	0,198	0,334	0,104	0,040	0,949	0,252	0,080	0,305	0,002	0,000	0,003	0,000	0,001	0,000	NO	0,001	0,000	2,271
1992	0,195	0,339	0,101	0,035	0,983	0,254	0,082	0,311	0,001	0,000	0,003	0,000	0,001	0,000	NO	0,001	0,000	2,306
1993	0,195	0,333	0,109	0,035	0,994	0,258	0,080	0,333	0,001	0,000	0,003	0,000	0,001	0,000	NO	0,001	0,000	2,345
1994	0,208	0,325	0,115	0,033	0,995	0,238	0,079	0,318	0,002	0,000	0,003	0,000	0,001	0,000	NO	0,001	0,000	2,319
1995	0,210	0,345	0,127	0,038	1,027	0,255	0,084	0,335	0,002	0,000	0,003	0,000	0,001	0,000	NO	0,001	0,000	2,428
1996	0,215	0,350	0,134	0,039	1,022	0,265	0,081	0,337	0,002	0,000	0,003	0,000	0,001	0,000	NO	0,000	0,000	2,450
1997	0,213	0,348	0,142	0,044	1,018	0,289	0,084	0,359	0,002	0,000	0,004	0,000	0,001	0,000	NO	0,001	0,000	2,504
1998	0,212	0,347	0,149	0,043	1,045	0,294	0,082	0,383	0,002	0,000	0,004	0,000	0,001	0,000	NO	0,001	0,000	2,563
1999	0,232	0,376	0,157	0,043	1,147	0,333	0,082	0,407	0,002	0,000	0,004	0,000	0,001	0,000	NO	0,000	0,000	2,785
2000	0,227	0,368	0,154	0,039	1,114	0,338	0,074	0,380	0,002	0,000	0,005	0,000	0,001	0,000	NO	0,001	0,000	2,701
2001	0,222	0,362	0,155	0,042	1,099	0,342	0,076	0,367	0,002	0,000	0,005	0,000	0,002	0,000	NO	0,001	0,000	2,675
2002	0,218	0,335	0,138	0,036	1,087	0,334	0,071	0,374	0,002	0,000	0,005	0,000	0,002	0,000	NO	0,001	0,000	2,602
2003	0,202	0,317	0,128	0,032	1,034	0,316	0,065	0,399	0,002	0,000	0,005	0,000	0,002	0,000	0,001	0,001	0,000	2,505
2004	0,197	0,308	0,121	0,030	1,009	0,309	0,065	0,399	0,002	0,000	0,006	0,000	0,002	0,000	0,002	0,001	0,000	2,451
2005	0,178	0,307	0,128	0,028	1,015	0,289	0,065	0,426	0,002	0,000	0,007	0,000	0,002	0,000	0,001	0,001	0,000	2,449
2006	0,166	0,306	0,124	0,026	1,008	0,269	0,060	0,396	0,002	0,000	0,007	0,000	0,002	0,000	0,001	0,001	0,000	2,368
2007	0,164	0,323	0,128	0,023	1,037	0,260	0,058	0,390	0,002	0,000	0,007	0,000	0,002	0,000	0,001	0,000	0,000	2,396
2008	0,149	0,316	0,147	0,027	1,063	0,254	0,056	0,379	0,002	0,000	0,007	0,000	0,002	0,000	0,001	0,000	0,000	2,403
2009	0,137	0,317	0,137	0,032	1,093	0,225	0,056	0,371	0,002	0,000	0,007	0,000	0,002	0,000	0,001	0,000	0,000	2,381
2010	0,123	0,326	0,147	0,031	1,134	0,194	0,056	0,386	0,002	0,001	0,007	0,000	0,002	0,000	0,001	0,000	0,000	2,411
2011	0,126	0,310	0,132	0,028	1,114	0,189	0,052	0,417	0,002	0,001	0,007	0,000	0,002	0,000	0,002	0,000	0,000	2,382
2012	0,127	0,303	0,118	0,024	1,101	0,182	0,046	0,425	0,002	0,001	0,008	0,000	0,003	0,000	0,001	0,000	0,000	2,340
2013	0,129	0,305	0,130	0,026	1,147	0,180	0,046	0,412	0,002	0,001	0,007	0,000	0,003	0,000	0,002	0,000	0,000	2,390
2014	0,129	0,335	0,141	0,030	1,162	0,172	0,044	0,411	0,002	0,001	0,007	0,000	0,003	0,000	0,001	0,000	0,000	2,439
2015	0,130	0,348	0,128	0,031	1,246	0,174	0,040	0,456	0,002	0,001	0,007	0,000	0,003	0,000	0,001	0,000	0,000	2,568
Trend (90 - 15)	**-24,4%**	**23,8%**	**47,5%**	**-8,5%**	**45,7%**	**-16,5%**	**-52,7%**	**30,4%**	**29,8%**	**841,7%**	**173,9%**	**-46,6%**	**176,1%**	**-57,7%**		**-79,9%**	**-15,7%**	**23,5%**

Source: SER.

Table 5-14 – N2O emission trends for IPCC Category 3B – Manure Management: 1990-2015 by livestock category (Gg)

years	calves	young cattle	Bulls 1-2	bulls >2	dairy cows	suckler cows	pigs reprod	fattening pigs	sheep	goats	horses	chicken	laying hens	other poultry	ostriches	rabbits	cervidae	total
1990	0,009	0,010	0,007	0,003	0,030	0,007	0,001	0,004	0,000	0,000	0,000	0,000	0,000	0,000	NO	0,000	0,000	0,071
1991	0,009	0,010	0,007	0,003	0,028	0,007	0,001	0,003	0,000	0,000	0,000	0,000	0,000	0,000	NO	0,000	0,000	0,070
1992	0,008	0,010	0,007	0,003	0,028	0,007	0,001	0,003	0,000	0,000	0,000	0,000	0,000	0,000	NO	0,000	0,000	0,069
1993	0,008	0,010	0,007	0,003	0,027	0,007	0,001	0,004	0,000	0,000	0,001	0,000	0,000	0,000	NO	0,000	0,000	0,068
1994	0,009	0,009	0,008	0,002	0,027	0,006	0,001	0,004	0,000	0,000	0,001	0,000	0,000	0,000	NO	0,000	0,000	0,067
1995	0,008	0,010	0,008	0,003	0,030	0,006	0,001	0,004	0,000	0,000	0,001	0,000	0,000	0,000	NO	0,000	0,000	0,071
1996	0,009	0,010	0,009	0,003	0,029	0,007	0,001	0,004	0,000	0,000	0,001	0,000	0,000	0,000	NO	0,000	0,000	0,072
1997	0,008	0,009	0,009	0,003	0,028	0,007	0,001	0,004	0,000	0,000	0,001	0,000	0,000	0,000	NO	0,000	0,000	0,072
1998	0,008	0,009	0,009	0,003	0,028	0,007	0,001	0,004	0,000	0,000	0,001	0,000	0,000	0,000	NO	0,000	0,000	0,071
1999	0,008	0,009	0,009	0,003	0,028	0,007	0,001	0,005	0,000	0,000	0,001	0,000	0,000	0,000	NO	0,000	0,000	0,071
2000	0,008	0,009	0,009	0,002	0,027	0,007	0,001	0,004	0,000	0,000	0,001	0,000	0,000	0,000	NO	0,000	0,000	0,069
2001	0,008	0,009	0,009	0,003	0,026	0,008	0,001	0,004	0,000	0,000	0,001	0,000	0,000	0,000	NO	0,000	0,000	0,068
2002	0,008	0,008	0,008	0,002	0,025	0,007	0,001	0,004	0,000	0,000	0,001	0,000	0,000	0,000	NO	0,000	0,000	0,065
2003	0,007	0,008	0,007	0,002	0,026	0,007	0,001	0,004	0,000	0,000	0,001	0,000	0,000	0,000	0,000	0,000	0,000	0,065
2004	0,007	0,008	0,007	0,002	0,025	0,007	0,001	0,004	0,000	0,000	0,001	0,000	0,000	0,000	0,000	0,000	0,000	0,063
2005	0,007	0,007	0,007	0,002	0,025	0,007	0,001	0,005	0,000	0,000	0,001	0,000	0,000	0,000	0,000	0,000	0,000	0,063
2006	0,007	0,007	0,007	0,002	0,024	0,007	0,001	0,004	0,000	0,000	0,001	0,000	0,000	0,000	0,000	0,000	0,000	0,061
2007	0,007	0,008	0,007	0,001	0,024	0,007	0,001	0,004	0,000	0,000	0,001	0,000	0,000	0,000	0,000	0,000	0,000	0,062
2008	0,007	0,007	0,008	0,002	0,024	0,008	0,001	0,004	0,000	0,000	0,001	0,000	0,000	0,000	0,000	0,000	0,000	0,063
2009	0,007	0,007	0,008	0,002	0,024	0,008	0,001	0,004	0,000	0,000	0,001	0,000	0,000	0,000	0,000	0,000	0,000	0,063
2010	0,007	0,007	0,008	0,002	0,025	0,008	0,001	0,004	0,000	0,000	0,001	0,000	0,000	0,000	0,000	0,000	0,000	0,064
2011	0,007	0,007	0,007	0,002	0,024	0,008	0,001	0,004	0,000	0,000	0,001	0,000	0,000	0,000	0,000	0,000	0,000	0,062
2012	0,007	0,007	0,007	0,001	0,024	0,007	0,001	0,004	0,000	0,000	0,001	0,000	0,000	0,000	0,000	0,000	0,000	0,060
2013	0,007	0,007	0,007	0,002	0,025	0,007	0,001	0,004	0,000	0,000	0,001	0,000	0,000	0,000	0,000	0,000	0,000	0,062
2014	0,007	0,008	0,008	0,002	0,025	0,007	0,001	0,004	0,000	0,000	0,001	0,000	0,000	0,000	0,000	0,000	0,000	0,064
2015	0,007	0,008	0,007	0,002	0,026	0,007	0,001	0,005	0,000	0,000	0,001	0,000	0,000	0,000	0,000	0,000	0,000	0,064
Trend ('90 - '15)	**-17,7%**	**-20,7%**	**2,3%**	**-36,5%**	**-13,4%**	**5,2%**	**-59,6%**	**20,2%**	**29,6%**	**842,3%**	**173,9%**	**-46,5%**	**176,7%**	**324,6%**		**-79,8%**	**-15,4%**	**-10,2%**

Source for Table 5-13 and Source: SER.

Table 5-14: SER.

Notes for Table 5-13 and Table 5-14: a) mules & asses are recorded together with horses

b) N2O emissions by livestock category exclude emissions from pasture, range & paddock (PRP).

Table 5-15 – N2O emission trends for IPCC Category 3B – Manure Management: 1990-2015 per AWMS (Mg)

year	aerobic lagoon	liquid	solid	pasture	digester	total
1990	NO	24,74	46,61	IE	NO	71,35
1991	NO	28,87	41,27	IE	NO	70,13
1992	NO	29,70	38,81	IE	NO	68,51
1993	NO	29,98	38,11	IE	NO	68,10
1994	NO	30,05	36,51	IE	NO	66,56
1995	NO	32,70	38,43	IE	NO	71,13
1996	NO	33,05	39,04	IE	NO	72,09
1997	NO	33,84	37,85	IE	NO	71,69
1998	NO	34,78	36,49	IE	NO	71,27
1999	NO	38,70	32,37	IE	NO	71,06
2000	NO	37,00	31,97	IE	NO	68,97
2001	NO	36,02	32,41	IE	NO	68,42
2002	NO	34,33	30,97	IE	NO	65,31
2003	NO	33,22	31,63	IE	NO	64,86
2004	NO	31,77	31,41	IE	NO	63,18
2005	NO	31,04	31,87	IE	NO	62,91
2006	NO	29,38	31,61	IE	NO	60,99
2007	NO	29,18	32,85	IE	NO	62,03
2008	NO	28,71	34,63	IE	NO	63,33
2009	NO	27,83	35,19	IE	NO	63,02
2010	NO	27,44	36,10	IE	NO	63,54
2011	NO	26,98	34,55	IE	NO	61,53
2012	NO	26,33	33,81	IE	NO	60,14
2013	NO	27,28	35,01	IE	NO	62,29
2014	NO	27,84	35,69	IE	NO	63,53
2015	NO	28,44	35,66	IE	NO	64,11
trend '90 -'15		**15%**	**-23%**			**-10%**

Source: SER.

Notes:

a) N_2O emissions from pasture, range & paddock (*PRP*) are excluded from the total N_2O emissions in IPCC Category 3B since they have to be accounted for in IPCC Sub-category 3D2 – Emissions from PRP Manure.

Table 5-16 – CH4 & N2O emission trends for IPCC Category 3B – Manure Management: 1990-2015

year	CH_4 (Gg)	N_2O (Gg)	Total (Gg CO2-eq)
1990	2,079	0,071	65,778
1991	2,271	0,070	69,436
1992	2,306	0,069	69,665
1993	2,345	0,068	70,345
1994	2,319	0,067	69,339
1995	2,428	0,071	73,033
1996	2,450	0,072	73,804
1997	2,504	0,072	74,818
1998	2,563	0,071	75,919
1999	2,785	0,071	80,512
2000	2,701	0,069	78,111
2001	2,675	0,068	77,378
2002	2,602	0,065	74,878
2003	2,505	0,065	72,718
2004	2,451	0,063	71,050
2005	2,449	0,063	70,928
2006	2,368	0,061	68,629
2007	2,396	0,062	69,540
2008	2,403	0,063	70,087
2009	2,381	0,063	69,538
2010	2,411	0,064	70,318
2011	2,382	0,062	69,094
2012	2,340	0,060	67,777
2013	2,390	0,062	69,494
2014	2,460	0,064	71,345
2015	2,568	0,064	73,796
trend '90 -'15	**24%**	**-10%**	**12%**

Source: SER.

5.3.3 Methodological issues – methane emissions

The IPCC Tier 2 method has been applied to all farm animal categories with the exception of cervidae for which the Tier 1 method has been used. It should be underlined that, essentially, the same calculation method characterizes both tiers. What distinguishes one tier from the other is the fact that, the average gross energy intake – as a component of the volatile solid daily excretion – is not a default value but, rather, the value obtained when estimating enteric fermentation methane related emissions with a Tier 2 method (see Section 5.2.3.2.1).

5.3.3.1 Activity data

Some activity data that have been extracted from national statistics, e.g. relating to the livestock population (see Table 5-4 in Section 5.2.1). Other activity data have been prepared by state departments under the authority of the Ministry of Agriculture: SER and ASTA. Some of these data (such as live-weight – see Table 5-7 in Section 5.2.3.1.2) are used to calculate parameters that are also needed for estimating enteric fermentation methane emissions (such as GE). They will not be presented again in this sub-section (see also Table 5-22 to Table 5-23 on activity data, parameters and coefficients used).

ASTA provided an expert judgment with regard to the recent situation of AWMS for each farm animal category. The percentage of each manure system has been estimated by this Administration on the basis of diverse information and its knowledge on agricultural practices in Luxembourg.

ASTA provided some additional information together with the AWMS estimates:

- liquid system: liquid manure storage is present around 6 months/year – during the winter season – for a certain number of farms. It is present the whole year for porcine breeding;
- solid storage: manure storage is present around 6 months/year – during the winter season – for a certain number of farms;
- pasture: this system is present around 6 months/year when the animals are grazing (summer season);
- anaerobic digester: since the end of the last century, biogas installations are more and more frequent at farms (and/or manure is more regularly collected to supply municipal or private biomethanization units). Hence, if the percentages presented in Table 6-21 could be seen as reasonable for the latest years, this would not be the case for the early 1990s. Indeed, as most of the installations producing biogas from manure are operating in Luxembourg since around the year 2000, they are usually very efficient and a gas tight coverage is present (expert judgment). Therefore emissions to be accounted for in CRF Sector 3 (leakages, as well as emissions due to storage in the digester) are very low (the methane produced should be recorded under the energy sector).

Consequently, due to the uncertainty going along with the first AWMS expert judgment, ASTA and SER decided to improve the AWMS breakdown for all the main animal categories. The result of this exercise is presented in Table 5-17 to Table 5-20.

Table 5-17 – Revised AWMS for all animal categories: 1990-2015 Liquid System

Years	Calves	Young cattle	Bulls 1-2	Bulls >2	dairy cows	suckler cows	pigs reprod	fattening pigs	sheep	goats	horses	chicken	laying hens	other poultry	ostriches	rabbits	cervidae
1990	19%	19%	19%	19%	23%	19%	95%	95%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1991	24%	24%	24%	24%	29%	24%	95%	95%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1992	25%	25%	25%	25%	31%	25%	95%	95%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1993	25%	25%	25%	25%	31%	25%	95%	95%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1994	26%	26%	26%	26%	32%	26%	95%	95%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1995	27%	27%	27%	27%	33%	27%	95%	95%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1996	27%	27%	27%	27%	33%	27%	95%	95%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1997	28%	28%	28%	28%	34%	28%	95%	95%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1998	29%	29%	29%	29%	36%	29%	95%	95%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1999	32%	32%	32%	32%	40%	32%	95%	95%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2000	31%	31%	31%	31%	40%	31%	93%	94%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2001	31%	31%	31%	31%	39%	31%	91%	93%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2002	30%	30%	30%	30%	38%	30%	89%	91%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2003	29%	29%	29%	29%	37%	29%	87%	90%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2004	28%	28%	28%	28%	36%	28%	85%	89%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2005	25%	27%	27%	27%	36%	24%	82%	88%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2006	22%	27%	27%	27%	36%	21%	80%	87%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2007	19%	27%	27%	27%	36%	17%	78%	86%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2008	16%	27%	26%	26%	36%	14%	76%	84%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2009	13%	27%	26%	26%	37%	11%	74%	83%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2010	10%	27%	26%	26%	37%	7%	72%	82%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2011	11%	27%	27%	27%	37%	7%	72%	82%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2012	11%	26%	26%	26%	37%	7%	72%	82%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2013	11%	26%	26%	26%	37%	7%	72%	82%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2014	11%	26%	26%	26%	37%	7%	72%	82%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2015	11%	26%	26%	26%	37%	7%	72%	82%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Source: SER & ASTA calculations (not published): prepared on 19 June 2007 and updated by SER in September 2014.

Table 5-18 – Revised AWMS for all animal categories: 1990-2015 Solid System

years	calves	Young cattle	Bulls 1-2	Bulls >2	Dairy cows	Suckler cows	Pigs reprod.	Fattening pigs	sheep	goats	horses	chicken	Laying hens	Other poultry	ostriches	rabbits	cervidae
1990	44%	32%	81%	81%	52%	32%	5%	5%	25%	25%	51%	100%	100%	100%	25%	100%	25%
1991	39%	27%	77%	77%	46%	27%	5%	5%	25%	25%	51%	100%	100%	100%	25%	100%	25%
1992	38%	26%	75%	75%	45%	26%	5%	5%	25%	25%	51%	100%	100%	100%	25%	100%	25%
1993	38%	26%	75%	75%	44%	26%	5%	5%	25%	25%	51%	100%	100%	100%	25%	100%	25%
1994	37%	25%	74%	74%	43%	25%	5%	5%	25%	25%	51%	100%	100%	100%	25%	100%	25%
1995	36%	24%	73%	73%	42%	24%	5%	5%	25%	25%	51%	100%	100%	100%	25%	100%	25%
1996	36%	24%	73%	73%	42%	24%	5%	5%	25%	25%	51%	100%	100%	100%	25%	100%	25%
1997	35%	23%	73%	73%	41%	23%	5%	5%	25%	25%	51%	100%	100%	100%	25%	100%	25%
1998	34%	22%	72%	72%	40%	22%	5%	5%	25%	25%	51%	100%	100%	100%	25%	100%	25%
1999	31%	19%	68%	68%	35%	19%	5%	5%	25%	25%	51%	100%	100%	100%	25%	100%	25%
2000	31%	19%	68%	68%	35%	19%	5%	5%	25%	25%	51%	100%	100%	100%	25%	100%	25%
2001	31%	19%	68%	68%	35%	19%	5%	5%	25%	25%	51%	100%	100%	100%	25%	100%	25%
2002	31%	19%	68%	68%	35%	19%	5%	5%	25%	25%	51%	100%	100%	100%	25%	100%	25%
2003	32%	20%	69%	69%	36%	20%	5%	5%	25%	25%	51%	100%	100%	100%	25%	100%	25%
2004	33%	20%	69%	69%	36%	21%	5%	5%	25%	25%	51%	100%	100%	100%	25%	100%	25%
2005	35%	20%	69%	69%	36%	23%	5%	5%	25%	25%	51%	100%	100%	100%	25%	100%	25%
2006	38%	19%	69%	69%	35%	26%	5%	5%	25%	25%	51%	100%	100%	100%	25%	100%	25%
2007	40%	19%	68%	68%	34%	29%	5%	5%	25%	25%	51%	100%	100%	100%	25%	100%	25%
2008	42%	18%	68%	68%	33%	32%	5%	5%	25%	25%	51%	100%	100%	100%	25%	100%	25%
2009	45%	18%	68%	68%	32%	35%	5%	5%	25%	25%	51%	100%	100%	100%	25%	100%	25%
2010	47%	18%	67%	67%	31%	38%	5%	5%	25%	25%	51%	100%	100%	100%	25%	100%	25%
2011	46%	18%	66%	66%	31%	38%	5%	5%	25%	25%	51%	100%	100%	100%	25%	100%	25%
2012	46%	18%	67%	67%	31%	38%	5%	5%	25%	25%	51%	100%	100%	100%	25%	100%	25%
2013	46%	18%	67%	67%	31%	38%	5%	5%	25%	25%	51%	100%	100%	100%	25%	100%	25%
2014	46%	18%	67%	67%	31%	38%	5%	5%	25%	25%	51%	100%	100%	100%	25%	100%	25%
2015	46%	18%	67%	67%	31%	38%	5%	5%	25%	25%	51%	100%	100%	100%	25%	100%	25%

Source: SER & ASTA calculations (not published): prepared on 19 June 2007 and updated by SER in September 2014.

Table 5-19 – Revised AWMS for all animal categories: 1990-2015 Digester

years	calves	Young cattle	Bulls 1-2	Bulls >2	Dairy cows	Suckler cows	Pigs reprod	Fattening pigs	sheep	goats	horses	chicken	Laying hens	Other poultry	ostriches	rabbits	cervidae
1990	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1991	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1992	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1993	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1994	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1995	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1996	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1997	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1998	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1999	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2000	1%	1%	1%	1%	1%	1%	2%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2001	1%	1%	1%	1%	1%	1%	4%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2002	2%	2%	2%	2%	2%	2%	6%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2003	2%	2%	2%	2%	3%	2%	8%	5%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2004	3%	3%	3%	3%	3%	3%	11%	6%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2005	3%	3%	4%	4%	4%	3%	13%	7%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2006	4%	4%	4%	4%	5%	4%	15%	8%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2007	4%	5%	5%	5%	5%	4%	17%	9%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2008	5%	5%	5%	5%	6%	5%	19%	11%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2009	5%	6%	6%	6%	6%	5%	21%	12%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2010	6%	6%	7%	7%	7%	6%	23%	13%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2011	6%	6%	7%	7%	7%	6%	23%	13%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2012	6%	6%	7%	7%	7%	6%	23%	13%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2013	6%	6%	7%	7%	7%	6%	23%	13%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2014	6%	6%	7%	7%	7%	6%	23%	13%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2015	6%	6%	7%	7%	7%	6%	23%	13%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Source: SER & ASTA calculations (not published): prepared on 19 June 2007 and updated by SER in September 2014.

Table 5-20 – Revised AWMS for all animal categories: 1990-2015 Pasture

years	calves	Young cattle	Bulls 1-2	Bulls >2	Dairy cows	Suckler cows	Pigs reprod	Fattening pigs	sheep	goats	horses	chicken	Laying hens	Other poultry	ostriches	rabbits	cervidae
1990	37%	49%	0%	0%	25%	49%	0%	0%	75%	75%	49%	0%	0%	0%	75%	0%	75%
1991	37%	49%	0%	0%	25%	49%	0%	0%	75%	75%	49%	0%	0%	0%	75%	0%	75%
1992	37%	49%	0%	0%	25%	49%	0%	0%	75%	75%	49%	0%	0%	0%	75%	0%	75%
1993	37%	49%	0%	0%	25%	49%	0%	0%	75%	75%	49%	0%	0%	0%	75%	0%	75%
1994	37%	49%	0%	0%	25%	49%	0%	0%	75%	75%	49%	0%	0%	0%	75%	0%	75%
1995	37%	49%	0%	0%	25%	49%	0%	0%	75%	75%	49%	0%	0%	0%	75%	0%	75%
1996	37%	49%	0%	0%	25%	49%	0%	0%	75%	75%	49%	0%	0%	0%	75%	0%	75%
1997	37%	49%	0%	0%	25%	49%	0%	0%	75%	75%	49%	0%	0%	0%	75%	0%	75%
1998	37%	49%	0%	0%	25%	49%	0%	0%	75%	75%	49%	0%	0%	0%	75%	0%	75%
1999	37%	49%	0%	0%	25%	49%	0%	0%	75%	75%	49%	0%	0%	0%	75%	0%	75%
2000	37%	49%	0%	0%	25%	49%	0%	0%	75%	75%	49%	0%	0%	0%	75%	0%	75%
2001	37%	49%	0%	0%	25%	49%	0%	0%	75%	75%	49%	0%	0%	0%	75%	0%	75%
2002	37%	49%	0%	0%	25%	49%	0%	0%	75%	75%	49%	0%	0%	0%	75%	0%	75%
2003	37%	49%	0%	0%	25%	49%	0%	0%	75%	75%	49%	0%	0%	0%	75%	0%	75%
2004	37%	49%	0%	0%	25%	49%	0%	0%	75%	75%	49%	0%	0%	0%	75%	0%	75%
2005	37%	49%	0%	0%	25%	49%	0%	0%	75%	75%	49%	0%	0%	0%	75%	0%	75%
2006	37%	49%	0%	0%	25%	49%	0%	0%	75%	75%	49%	0%	0%	0%	75%	0%	75%
2007	37%	49%	0%	0%	25%	49%	0%	0%	75%	75%	49%	0%	0%	0%	75%	0%	75%
2008	37%	49%	0%	0%	25%	49%	0%	0%	75%	75%	49%	0%	0%	0%	75%	0%	75%
2009	37%	49%	0%	0%	25%	49%	0%	0%	75%	75%	49%	0%	0%	0%	75%	0%	75%
2010	37%	49%	0%	0%	25%	49%	0%	0%	75%	75%	49%	0%	0%	0%	75%	0%	75%
2011	37%	49%	0%	0%	25%	49%	0%	0%	75%	75%	49%	0%	0%	0%	75%	0%	75%
2012	37%	49%	0%	0%	25%	49%	0%	0%	75%	75%	49%	0%	0%	0%	75%	0%	75%
2013	37%	49%	0%	0%	25%	49%	0%	0%	75%	75%	49%	0%	0%	0%	75%	0%	75%
2014	37%	49%	0%	0%	25%	49%	0%	0%	75%	75%	49%	0%	0%	0%	75%	0%	75%
2015	37%	49%	0%	0%	25%	49%	0%	0%	75%	75%	49%	0%	0%	0%	75%	0%	75%

Source: SER & ASTA calculations (not published): prepared on 19 June 2007 and updated by SER in September 2014.

Compared previous submissions (2014v1.3), AWMS shares for all animal categories have been revised. In 2010, the yearly agricultural census[123] has been completed by a dedicated survey on agricultural production methods (SAPM).[124] Based on the results of the SAPM, the SER produced interpolated AWMS shares for the years 2000 to 2015, i.e. using the shares as derived from the 2010 SAPM.

5.3.3.2 Emission factors

EFs for manure management related methane emissions are actually IEFs obtained by combining, for each livestock category, the volatile solids excreted daily by the animals (or volatile solid daily excretion, *VS* in kg-dm per day), the maximum methane producing capacity for the manure (or methane producing potential, *Bo* in m^3 CH_4/kg of VS) and the sum of the fractions of animals by AWMS (in %) multiplied by their corresponding methane conversion factor (*MCF* in %):

$$IEF_i = VS_i \; x \; 365.242199 \; x \; Bo_i \; x \; 0.67 \; x \; [\sum_j MCF_j \; x \; AWMS_{ij}]$$

with j = the various AWMS identified for each livestock category i

IEF_i expressed in kg CH_4/head/year

the factor 0.67 expressed in kg/m^3

➔ see equation 10.23 of the 2006 IPCC GLs.

For most of the farm animal categories, VS is calculated using equation 10.24 of the 2006 IPCC GLs which combines average gross energy intake (*GE*), digestible energy of the feed (*DE*) and the ash content of the manure (*ASH*). It is at that level that the distinction between tiers is made for manure management related methane emissions. Tier 2 is indicated for those animal categories for which GE is not a default value but rather an estimated value, whereas Tier 1 is specified when a default GE has been chosen to determine VS. GE being one of the parameters needed for estimating enteric fermentation methane emissions, values obtained in that case have been applied for estimating manure management related methane emissions.

Table 5-21 indicates, for each animal category, which method has been used to estimate methane emissions as well as the corresponding IEF type.

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123 See http://www.ser.public.lu/statistik/agrarstrukturen/statec_15_mai_pluriannuel.pdf.

124 The SAPM will be repeated from time to time. A new survey will be conducted 2014-2015.

Table 5-21 – Method and type of EF used in the inventory

Livestock category	Estimation method	IEF
3B - manure management – calves	T2	CS
3B - manure management – young cattle	T2	CS
3B - manure management – bulls	T2	CS
3B - manure management – bulls > 2 years	T2	CS
3B - manure management – dairy cows	T2	CS
3B - manure management – suckler cows	T2	CS
3B - manure management - pigs reproduction	T2	CS
3B - manure management - fattening pigs	T2	CS
3B - manure management - sheep	T2	CS
3B - manure management - goats	T2	CS
3B - manure management - horses (1)	T2	CS
3B - manure management – chicken	T2	CS
3B - manure management - laying hens	T2	CS
3B - manure management – other poultry	T2	CS
3B - manure management - ostriches	T2	CS
3B - manure management - rabbits	T2	CS
3B - manure management – cervidae	T1	D

Source: MDDI-DEV.

Abbreviations: T1 = Tier 1 ; T2 = Tier 2 ; CS = Country Specific ; D = IPCC Default

Note: (1) Mules and asses are included in the category horses

5.3.3.2.1 Tier 2 method – All animal categories except cervidae

The IEF has been calculated by combining the following activity data, coefficients and parameters:

Table 5-22 – Activity data, coefficients and parameters used for IPCC Sub-category 3B1 – Cattle

AD, parameter, coefficient	Unit	Source(s)	Type of value
Livestock (# of heads)	#	SER & STATEC	AD (see Table 6-4)
(Live) Weight or Typical Animal Mass (average)	kg	SER, not published	AD (see Table 6-7), invariable
Gross Energy Intake (average)	MJ/day	equation 10.16 – 2006 IPCC GLs Table 10A.4-9 – 2006 IPCC GLs	calculated
Digestible Energy	%	based on table 10.2 - 2006 IPCC Guidelines	default for Western Europe
Ash Content of the Manure	%	table B-1 – 1996 Revised IPCC Guidelines	default
Volatile Solid Daily Excretion	kg-dm/day	equation 10.24 – 2006 IPCC GLs	calculated
CH_4 Producing Potential	$m^3 CH_4$/kg VS	Table 10A.4-9 – 2006 IPCC GLs	default for Western Europe
Manure System/AWMS	%	SER & ASTA, not published	expert judgment, survey results and interpolated values (see Table 6-20)
CH_4 Conversion Factor	%	Table 10A.4-9 – 2006 IPCC GLs	default for a cool region

5.3.3.2.2 Tier 1 method – Cervidae

For cervidae, the IEF is the default manure management EF for a cool region in developed countries presented in Table 10-16 of the Revised 1996 IPCC Guidelines. More details are provided in Table 5-23.

Table 5-23 – Activity data, coefficients and parameters used for IPCC Sub-category cervidae

AD, parameter, coefficient	Unit	Source(s)	Type of value
Livestock (# of heads)	#	SER & STATEC	AD (see Table 6-4)
(Live) Weight or Typical Animal Mass (average)	kg	SER, not published	AD (see Table 6-7), invariable
Gross Energy Intake (average)	MJ/day	Table 10A.4-9 – 2006 IPCC GLs	default for developed countries
Digestible Energy	%	based on table 10.2 - 2006 IPCC Guidelines	default for developed countries
Ash Content of the Manure	%	table B-7 – Revised 1996 IPCC Guidelines	default for developed countries
Volatile Solid Daily Excretion	kg-dm/day	Table 10A.4-9 – 2006 IPCC GLs	default for developed countries
CH_4 Producing Potential	m^3 CH_4/kg VS	Table 10A.4-9 – 2006 IPCC GLs	default for developed countries
Manure System/AWMS	%	SER & ASTA, not published	expert judgment (see Table 6-19), invariable
CH_4 Conversion Factor	%	Table 10A.4-9 – 2006 IPCC GLs	default for a cool region

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5.3.3.2.3 Methane IEFs for 3.B – Manure Management

Table 5-24 presents the IEFs obtained for each farm animal category using the Tier 1 or Tier 2 methods described above.

Table 5-24 – CH4 IEFs trends for IPCC Category 3B – Manure Management: 1990-2015 (kg CH_4 / animal)

years	calves	young cattle	Bulls 1-2	bulls > 2	dairy cows	suckler cows	pigs reprod	fattening pigs	sheep	goats	horses	chicken	laying hens	other poultry	ostriches	rabbits	cervidae
1990	2,90	4,79	6,70	6,29	14,53	8,45	8,23	5,37	0,11	0,13	1,56	0,01	0,03	0,03	5,68	0,08	0,22
1991	3,34	5,56	7,66	7,19	17,07	9,82	8,23	5,37	0,11	0,13	1,56	0,01	0,03	0,03	5,68	0,08	0,22
1992	3,46	5,76	7,91	7,42	17,58	10,17	8,23	5,37	0,11	0,13	1,56	0,01	0,03	0,03	5,68	0,08	0,22
1993	3,50	5,82	7,99	7,50	18,24	10,31	8,23	5,37	0,11	0,13	1,56	0,01	0,03	0,03	5,68	0,08	0,22
1994	3,59	5,97	8,18	7,67	18,67	10,55	8,23	5,37	0,11	0,13	1,56	0,01	0,03	0,03	5,68	0,08	0,22
1995	3,65	6,07	8,30	7,79	19,25	10,74	8,23	5,37	0,11	0,13	1,56	0,01	0,03	0,03	5,68	0,08	0,22
1996	3,65	6,07	8,30	7,79	19,24	10,76	8,23	5,37	0,11	0,13	1,56	0,01	0,03	0,03	5,68	0,08	0,22
1997	3,73	6,22	8,49	7,97	19,98	11,02	8,23	5,37	0,11	0,13	1,56	0,01	0,03	0,03	5,68	0,08	0,22
1998	3,83	6,38	8,70	8,16	20,63	11,32	8,23	5,37	0,11	0,13	1,56	0,01	0,03	0,03	5,68	0,08	0,22
1999	4,18	6,98	9,45	8,86	22,84	12,36	8,23	5,37	0,11	0,13	1,56	0,01	0,03	0,03	5,68	0,08	0,22
2000	4,14	6,91	9,37	8,79	22,91	12,23	8,16	5,34	0,11	0,13	1,56	0,01	0,03	0,03	5,68	0,08	0,22
2001	4,08	6,82	9,25	8,68	22,98	12,04	8,08	5,31	0,11	0,13	1,56	0,01	0,03	0,03	5,68	0,08	0,22
2002	4,05	6,77	9,19	8,63	23,15	11,95	8,01	5,29	0,11	0,13	1,56	0,01	0,03	0,03	5,68	0,08	0,22
2003	3,94	6,58	8,97	8,42	23,00	11,63	7,93	5,26	0,11	0,13	1,56	0,01	0,03	0,03	5,68	0,08	0,22
2004	3,87	6,47	8,83	8,28	22,96	11,42	7,86	5,23	0,11	0,13	1,56	0,01	0,03	0,03	5,68	0,08	0,22
2005	3,62	6,50	8,84	8,30	23,37	10,51	7,78	5,21	0,11	0,13	1,56	0,01	0,03	0,03	5,68	0,08	0,22
2006	3,37	6,54	8,86	8,31	23,88	9,60	7,71	5,18	0,11	0,13	1,56	0,01	0,03	0,03	5,68	0,08	0,22
2007	3,11	6,57	8,87	8,33	24,16	8,69	7,64	5,15	0,11	0,13	1,56	0,01	0,03	0,03	5,68	0,08	0,22
2008	2,86	6,61	8,89	8,34	24,40	7,78	7,56	5,12	0,11	0,13	1,56	0,01	0,03	0,03	5,68	0,08	0,22
2009	2,60	6,64	8,90	8,35	24,66	6,87	7,49	5,10	0,11	0,13	1,56	0,01	0,03	0,03	5,68	0,08	0,22
2010	2,35	6,68	8,92	8,37	25,19	5,96	7,41	5,07	0,11	0,13	1,56	0,01	0,03	0,03	5,68	0,08	0,22
2011	2,42	6,61	9,21	8,65	25,26	5,95	7,41	5,07	0,11	0,13	1,56	0,01	0,03	0,03	5,68	0,08	0,22
2012	2,41	6,57	9,02	8,46	25,34	5,95	7,41	5,07	0,11	0,13	1,56	0,01	0,03	0,03	5,68	0,08	0,22
2013	2,41	6,57	9,02	8,46	24,83	5,94	7,41	5,07	0,11	0,13	1,56	0,01	0,03	0,03	5,68	0,08	0,22
2014	2,41	6,57	9,02	8,46	25,15	5,94	7,41	5,07	0,21	0,13	1,56	0,01	0,03	0,03	5,68	0,08	0,22
2015	2,41	6,57	9,02	8,46	26.55	5,94	7,41	5,07	0,21	0,13	1,56	0,01	0,03	0,03	5,68	0,08	0,22
trend (90 - 15)	**-17%**	**37%**	**35%**	**35%**	**83%**	**-30%**	**-10%**	**-6%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**		**0%**	**0%**
IEF type	CS	CS	CS	CS	CS	CS	CS	CS	D	D	D	D	D	D	D	D	D

Source: SER.

Notes:

a) mules & asses were recorded together with horses.

5.3.4 Methodological issues – nitrous oxide emissions

The IPCC Tier 2 method has been applied to all farm animal categories.

5.3.4.1 Activity data

The following activity data were used to calculate N_2O emissions per AWMS and animal category:

- livestock population extracted from national statistics: see Table 5-4 in Section 5.2.3.1;
- AWMS shares per animal category: see Table 5-17 to Table 5-20 in Section 5.3.3.1;
- Yearly nitrogen excretion (Nex_i) per head for each animal category i: see Table 5-25.

Most of the Nex_i proposed by SER have been prepared in the framework of an EC Directive on nitrate and good agricultural practice [125] and/or for the OECD Agro-environmental Indicators Database. The Nex_i also apply for the cross compliance measures provided for the single farm payment scheme of the CAP.[126] Since they are not officially published in Luxembourg, Nex_i values should therefore be considered as an expert judgment.

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125 Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources.

126 Council Regulation (EC) No 1782/2003 of 29 September 2003 establishing common rules for direct support schemes under the common agricultural policy and establishing certain support schemes for farmers.

Table 5-25 – Nitrogen excretion for farm animals reported in the inventory (kg N / animal)

years	calves	young cattle	Bulls 1-2	bulls >2	dairy cows	suckler cows	pigs reprod	fattening pigs	sheep	goats	horses	chicken	laying hens	other poultry	ostriches	rabbits	cervidae
1990	29,75	42,5	68	68	85	68	17	7,65	12,75	12,75	68	0,255	0,595	0,85	2,975	3,6125	34
1991	29,75	42,5	68	68	85	68	17	7,65	12,75	12,75	68	0,255	0,595	0,85	2,975	3,6125	34
1992	29,75	42,5	68	68	85	68	17	7,65	12,75	12,75	68	0,255	0,595	0,85	2,975	3,6125	34
1993	29,75	42,5	68	68	85	68	17	7,65	12,75	12,75	68	0,255	0,595	0,85	2,975	3,6125	34
1994	29,75	42,5	68	68	85	68	17	7,65	12,75	12,75	68	0,255	0,595	0,85	2,975	3,6125	34
1995	29,75	42,5	68	68	93,5	68	17	7,65	12,75	12,75	68	0,255	0,595	0,85	2,975	3,6125	34
1996	29,75	42,5	68	68	93,5	68	17	7,65	12,75	12,75	68	0,255	0,595	0,85	2,975	3,6125	34
1997	29,75	42,5	68	68	93,5	68	17	7,65	12,75	12,75	68	0,255	0,595	0,85	2,975	3,6125	34
1998	29,75	42,5	68	68	93,5	68	17	7,65	12,75	12,75	68	0,255	0,595	0,85	2,975	3,6125	34
1999	29,75	42,5	68	68	93,5	68	17	7,65	12,75	12,75	68	0,255	0,595	0,85	2,975	3,6125	34
2000	29,75	42,5	68	68	93,5	68	17	7,65	12,75	12,75	68	0,255	0,595	0,85	2,975	3,6125	34
2001	29,75	42,5	68	68	93,5	68	17	7,65	12,75	12,75	68	0,255	0,595	0,85	2,975	3,6125	34
2002	29,75	42,5	68	68	93,5	68	17	7,65	12,75	12,75	68	0,255	0,595	0,85	2,975	3,6125	34
2003	29,75	42,5	68	68	102	68	17	7,65	12,75	12,75	68	0,255	0,595	0,85	2,975	3,6125	34
2004	29,75	42,5	68	68	102	68	17	7,65	12,75	12,75	68	0,255	0,595	0,85	2,975	3,6125	34
2005	29,75	42,5	68	68	102	68	17	7,65	12,75	12,75	68	0,255	0,595	0,85	2,975	3,6125	34
2006	29,75	42,5	68	68	102	68	17	7,65	12,75	12,75	68	0,255	0,595	0,85	2,975	3,6125	34
2007	29,75	42,5	68	68	102	68	17	7,65	12,75	12,75	68	0,255	0,595	0,85	2,975	3,6125	34
2008	29,75	42,5	68	68	102	68	17	7,65	12,75	12,75	68	0,255	0,595	0,85	2,975	3,6125	34
2009	29,75	42,5	68	68	102	68	17	7,65	12,75	12,75	68	0,255	0,595	0,85	2,975	3,6125	34
2010	29,75	42,5	68	68	102	68	17	7,65	12,75	12,75	68	0,255	0,595	0,85	2,975	3,6125	34
2011	29,75	42,5	68	68	102	68	17	7,65	12,75	12,75	68	0,255	0,595	0,85	2,975	3,6125	34
2012	29,75	42,5	68	68	102	68	17	7,65	12,75	12,75	68	0,255	0,595	0,85	2,975	3,6125	34
2013	29,75	42,5	68	68	102	68	17	7,65	12,75	12,75	68	0,255	0,595	0,85	2,975	3,6125	34
2014	29,75	42,5	68	68	102	68	17	7,65	12,75	12,75	68	0,255	0,595	0,85	2,975	3,6125	34
2015	29,75	42,5	68	68	102	68	17	7,65	12,75	12,75	68	0,255	0,595	0,85	2,975	3,6125	34

Source: SER, not published.

5.3.4.2 Emission factors

Since the Tier 2 method has been applied to estimate manure management N_2O related emissions, default EFs have been used for all animal categories. These EFs are presented in Table 5-26 and are extracted from table 10.21 of the 2006 IPCC GLs.

Table 5-26 – Default EFs for N_2O emissions per selected AWMS

	AWMS			
	Liquid System	Solid Storage	Pasture	Digester
Default EF (kg N_2O-N/kg N)	0.005	0.005	NA	0

Nitrous oxide emissions are obtained by adding up, for each AWMS, nitrogen excretion estimated for each animal category. This gives the total nitrogen excretion per AWMS for all the livestock categories included in the inventory (Nex_j). Then, these total nitrogen excretion values per AWMS (in kg N/year) are multiplied by the corresponding EF of Table 5-26. This multiplication provides nitrous oxide losses per AWMS in kg N_2O-N/year. To obtain N_2O emissions, the latest figure should be multiplied by the molecular weight ratio (44/28) ➔ see below and equation 10.25 of the 2006 IPCC GLs.

For each animal category, nitrogen excretion per AWMS was calculated using the following formula:

$$Nex_{ij} = Nex_i * (\#\ of\ heads)_i * AWMS_{ij}$$

with j = the various AWMS identified for each livestock category i

Nex_{ij} expressed in kg N/year

Nex_i expressed in kg N/head/year (provided in Table 6-26)

and, therefore:

$$Nex_j = \sum_i Nex_{ij}$$

with Nex_j = the total nitrogen excretion per AWMS j in kg N/year

then, N_2O emissions per AWMS are:

$$N_2O_j = [Nex_j\ xEF_j] * (44/28)$$

with Nex_j = the total nitrogen excretion per AWMS j in kg N/year

EF_j expressed in kg N_2O-N/kg N (see Table 6-27)

Nitrous oxide emissions reported under the source category manure management are the sum of the N_2O_j **with the exception of j = Pasture**. Indeed, to avoid double counting, and to allow for certain logic in the emission reporting, emissions related to Pasture are accounted for under IPCC Category 3D – Agricultural Soils (see Section 5.5).

5.3.5 Category-specific recalculations including changes made in response to the review process

No recalculations were made.

5.3.6 Category specific uncertainty

The uncertainty associated with activity statistics is generally believed to be quite small. Animal numbers' uncertainty is estimated to be 0.2%.

Manure application emission factors follow a 30% uncertainty for CH_4 and 100% for N_2O. Table 5-27 depicts all the uncertainties used to determine the total propagated error for category 3B.

Table 5-27: Uncertainties used in category 3B

Category	Description	Uncertainty	Source
EF mm CH_4 T1	T1 methane emission factor for manure management	30%	see 10.4.4. p 10.48
b0	maximum methane producing capacity for manure produced by livestock category	15%	see Tab 10A.4-9
Vs non dairy	daily volatile solid excreted for livestock category	25%	see Tab 10A.4-9
Vs dairy	daily volatile solid excreted for livestock category	20%	see Tab 10A.4-9
Vs other animals	daily volatile solid excreted for livestock category	50%	see Tab 10A.4-9
ms solid	proportion solid mms	10%	estimation by sector expert
ms liquid	proportion liquid mms	10%	estimation by sector expert
ms pasture	proportion pasture mms	10%	estimation by sector expert
ms digester	proportion digester mms	10%	estimation by sector expert
N.ex	Nitrogen excretion factor	20%	estimation by sector expert
EF mm N_2O T2	T2 N_2O emission factor for mm	100%	see 10.5.5 p 10.66
frac.gas	percent of managed manure nitrogen for livestock category that volatilises as NH_3 and NO_X in the manure management system	90%	tab 10.22 p 10.65

5.3.7 Category-specific QA/QC and verification

Consistency and completeness checks have been performed before starting the calculations, as well as during the work process. Also the tools embedded in CRF Reporter were of great utility. The plausibility of the estimates, as well as the calculation methods were extensively discussed by the sector experts from SER and ASTA.

5.3.8 Planned improvement

No improvement is planned, as all possible improvements took place while establishing the GHG inventory for the agricultural sector according to 2006 IPCC Guidelines.

5.4 Rice Cultivation (IPCC Source Category 3.C)

This source category does not exist in Luxembourg.

5.5 Agricultural Soils (IPCC Source Category 3.D)

This section describes the estimation of nitrous oxide emissions linked to agricultural soils, whether these are direct or indirect emissions originating from crops or from spreading on soils. In 2015, this source category was responsible for 90.41% of agricultural nitrous oxide emissions and for 52.4% of the total nitrous oxide emissions estimated for Luxembourg. It represented 30.78% of the total emissions due to agricultural activities and 1.5% of the total GHG emissions in CO_2e (excluding LULUCF).

5.5.1 Key source

With 1.4% of the total GHG emissions in CO_2e, excluding LULUCF in 2015 (1.5% of the total GHG emissions in CO_2e, including LULUCF), nitrous oxide emissions from agricultural soils (IPCC Category 3D) is a key source if LULUCF is excluded. It has been a key source in both cases without interruption since 1990.

5.5.2 Source category description

The source category agricultural soils covers:

- direct soil emissions (IPCC Sub-category 3D): nitrogen input to soils (such as application of synthetic fertilizers and manure) and nitrogen fixed by crops or crop residues;
- nitrogen excretion on pasture (IPCC Sub-category 3D) calculated under IPCC Category 3B but to be reported in this category (see Section 5.3.2);
- indirect soil emissions (IPCC Sub-category 3D) due to atmospheric deposition as well as to nitrogen from fertilizers and animals that is lost through leaching and run-off.

Since 1990, agricultural soil N_2O related emissions declined by almost 23%.

CO_2 emissions from soils due to liming and C-fertiliser are provisional as there is no data on dolomite and C-fertiliser usage available. The only data available is of lower quality and represents the usage of limestone in agriculture.

Table 5-28 – N_2O emission trends (Gg) for IPCC Category 3D – Agricultural Soils: 1990-2015

year	synthetic fertilizer	manure	sewage sludge	compost	grazing	crop residues	mineralization	Organic soils	other	atmospheric deposition	nitrogen leaching	total	method
1990	0,309	0,086	0,006	0,000	0,064	0,000	NO	NO	NO	0,062	0,105	0,633	T1
1991	0,334	0,084	0,006	0,000	0,064	0,000	NO	NO	NO	0,064	0,110	0,663	T1
1992	0,305	0,082	0,006	0,000	0,063	0,000	NO	NO	NO	0,061	0,103	0,619	T1
1993	0,289	0,082	0,006	0,000	0,062	0,000	NO	NO	NO	0,059	0,099	0,597	T1
1994	0,284	0,080	0,007	0,000	0,060	0,000	NO	NO	NO	0,058	0,097	0,585	T1
1995	0,285	0,085	0,006	0,000	0,063	0,000	NO	NO	NO	0,059	0,099	0,598	T1
1996	0,281	0,086	0,006	0,000	0,064	0,000	NO	NO	NO	0,059	0,098	0,594	T1
1997	0,275	0,086	0,006	0,000	0,063	0,000	NO	NO	NO	0,058	0,097	0,585	T1
1998	0,279	0,085	0,006	0,000	0,062	0,000	NO	NO	NO	0,059	0,097	0,588	T1
1999	0,284	0,084	0,006	0,000	0,063	0,000	NO	NO	NO	0,059	0,098	0,594	T1
2000	0,280	0,083	0,005	0,000	0,062	0,000	NO	NO	NO	0,058	0,097	0,586	T1
2001	0,239	0,083	0,005	0,000	0,062	0,000	NO	NO	NO	0,054	0,088	0,531	T1
2002	0,249	0,081	0,005	0,000	0,061	0,000	NO	NO	NO	0,054	0,089	0,539	T1
2003	0,203	0,081	0,004	0,000	0,061	0,000	NO	NO	NO	0,049	0,078	0,476	T1
2004	0,257	0,080	0,004	0,000	0,060	0,000	NO	NO	NO	0,054	0,090	0,546	T1
2005	0,224	0,081	0,004	0,000	0,060	0,000	NO	NO	NO	0,051	0,083	0,503	T1
2006	0,221	0,080	0,005	0,000	0,060	0,000	NO	NO	NO	0,051	0,082	0,498	T1
2007	0,209	0,082	0,005	0,000	0,062	0,000	NO	NO	NO	0,051	0,081	0,491	T1
2008	0,209	0,085	0,005	0,000	0,063	0,000	NO	NO	NO	0,052	0,082	0,496	T1
2009	0,210	0,086	0,004	0,000	0,064	0,000	NO	NO	NO	0,052	0,082	0,498	T1
2010	0,210	0,088	0,003	0,000	0,065	0,000	NO	NO	NO	0,052	0,082	0,501	T1
2011	0,234	0,085	0,004	0,000	0,064	0,000	NO	NO	NO	0,054	0,087	0,528	T1
2012	0,215	0,083	0,005	0,000	0,062	0,000	NO	NO	NO	0,052	0,082	0,500	T1
2013	0,219	0,086	0,004	0,000	0,063	0,000	NO	NO	NO	0,053	0,084	0,510	T1
2014	0,200	0,088	0,005	0,000	0,064	0,000	NO	NO	NO	0,051	0,080	0,489	T1
2015	0,200	0,089	0,004	0,000	0,066	0,000	NO	NO	NO	0,052	0,081	0,490	T1
trend ('90 - '15)	**-35%**	**3%**	**-38%**		**2%**	**82%**				**-17%**	**-23%**	**-23%**	

Source: SER.

5.5.3 Methodological issues

According to IPCC Guidelines, estimating nitrous oxide emissions from agricultural soils requests the use of certain fractions. For most of these fractions, as shown in Table 5-29, Luxembourg did use default values presented in the 2006 IPCC Guidelines.

Table 5-29 – Fractions used for estimating N_2O emissions for IPCC Category 3D – Agricultural Soils

Fraction	Description	Unit	Value	Source
$Frac_{BURN}$	Fraction of crop residue burned	kg N/kg crop-N	NO	
$Frac_{FUEL}$	Fraction of livestock N excretion in excrements burned for fuel	kg N/kg N excreted	NO	
$Frac_{GASF}$	Fraction of synthetic fertilizer N applied to soils that volatilizes as NH_3 and NOx	kg NH_3-N+NOx-N/kg synthetic fertilizer N applied	0.1	table 11.3– 2006 IPCC Guidelines
$Frac_{GASM}$	Fraction of livestock N excretion that volatilizes as NH_3 and NOx	kg NH_3-N+NOx-N/kgN excreted	0.2	table 11.3– 2006 IPCC Guidelines
$Frac_{GRAZ}$/$Frac_{PRP}$	Fraction of livestock N excreted and deposited onto soil during grazing	% of kgN/year	CRF	Equation 11.5 – 2006 IPCC Guidelines
$Frac_{LEACH}$	Fraction of N input to soils that is lost through leaching and run-off	kg N/kg fertilizer or manure-N	0.3	table 11.3– 2006 IPCC Guidelines
$Frac_{R}$	Fraction of total above-ground crop biomass that is removed from the field as a crop product	kg N/kg crop-N	0	Equation 11.6 – 2006 IPCC Guidelines

Consequently, the use of default fractions – combined with default EFs – implies that Tier 1 methods have been applied for estimating direct and indirect N_2O emissions from agricultural soils.

5.5.3.1 Activity data

Only a limited number of activity data has been used to provide N_2O estimates for IPCC Category 3D. Some activity data are extracted from national statistics:

- the consumption of synthetic fertilizers: see Table 5-30;
- various crop productions: see Table 5-31.

For emissions due to sewage sludge spreading on fields, data have been estimated by both the MDDI-DEV and the MDDI-AEV (Environment Agency) on the basis of annual reports and official statistics on wastewater treatment in Luxembourg. Most of the data were calculated using the 2006 IPCC Guidelines for the AFOLU-sector (equations 10.34, 11.3, 11.5, 11.6 IPCC 2006 GLs).

Table 5-30 – Activity data (kg N) for IPCC Category 3D: 1990-2015

year	synthetic fertilizer	manure	sewage sludge	compost	grazing	crop residues	mineralization	Organic soils	other	atmospheric deposition	nitrogen leaching
1990	19689000	5497491	377061,000	0,000	4086750	5298,802	NO	NO	NO	3961160	8896680
1991	21245000	5370777	377284,100	0,000	4092205	5544,910	NO	NO	NO	4092553	9327243
1992	19381000	5249383	381628,700	0,000	4006505	5496,610	NO	NO	NO	3865603	8707204
1993	18400000	5212219	396462,700	0,000	3938896	5502,707	NO	NO	NO	3749516	8385924
1994	18054000	5086157	414636,300	0,000	3816895	4797,335	NO	NO	NO	3668938	8212946
1995	18140000	5427642	411720,700	0,000	4010550	5372,183	NO	NO	NO	3783983	8398586
1996	17860000	5500531	357610,100	0,000	4066881	6246,764	NO	NO	NO	3771005	8337381
1997	17500000	5446918	374792,000	0,000	4018484	5848,192	NO	NO	NO	3718039	8203813
1998	17773500	5405287	375887,900	0,000	3960494	5964,414	NO	NO	NO	3725684	8256340
1999	18047000	5364494	373871,600	0,000	3989564	5722,413	NO	NO	NO	3750286	8334196
2000	17819000	5272489	326925,300	13913,040	3964428	8237,408	NO	NO	NO	3697451	8221498
2001	15200000	5303872	306380,100	6979,140	3968581	8477,942	NO	NO	NO	3437162	7438287
2002	15835000	5138317	324231,200	6631,140	3862026	9039,267	NO	NO	NO	3449741	7552573
2003	12905000	5167971	247494,400	5091,240	3849979	9541,843	NO	NO	NO	3144607	6655523
2004	16355000	5106723	226908,600	5696,760	3817560	10313,660	NO	NO	NO	3466878	7656661
2005	14230000	5142831	240685,000	12322,680	3815846	9788,725	NO	NO	NO	3265337	7035442
2006	14034000	5059983	304366,500	11082,060	3794273	9119,903	NO	NO	NO	3237341	6963847
2007	13312000	5236935	334226,500	11198,640	3965505	9704,312	NO	NO	NO	3240773	6860871
2008	13329000	5422014	294597,000	14031,360	4037704	10790,910	NO	NO	NO	3286569	6932441
2009	13383500	5476527	235167,700	14732,580	4072027	11212,160	NO	NO	NO	3298041	6957950
2010	13354400	5605880	203646,700	17008,500	4124963	9688,497	NO	NO	NO	3325740	6994676
2011	14866600	5425923	247104,400	11339,580	4045125	9079,607	NO	NO	NO	3432558	7381552
2012	13675000	5291947	327707,300	10523,520	3963008	9653,043	NO	NO	NO	3286137	6983352
2013	13944450	5492117	266139,900	8506,860	4029913	10012,290	NO	NO	NO	3353780	7125342
2014	12714469	5596427	309777,800	13135,260	4088183	10763,150	NO	NO	NO	3272952	6819827
2015	12714469	5653338	232142,400	11517,060	4170409	9647,373	NO	NO	NO	3284928	6837457

Sources: SER: http://www.ser.public.lu/statistik/betriebsmittel/duenger.pdf

5.5.3.1.1 Fertilizers use

Only nitrogenous fertilizers have been considered as synthetic fertilizers since these are the ones generating nitrous oxide emissions. Up to 1998 included, statistics were not recording fertilizer application but well fertilizer sales in Luxembourg. Therefore, for the years prior to 1999, the hypothesis that fertilizers consumption/application equals fertilizer sales (i.e. no stocks and stock changes) has been made.

5.5.3.1.2 Crop production

The various crop productions are to be recorded for IPCC Category 3F – Field Burning of Agricultural Residues. Nevertheless being necessary to calculate some direct soil emissions, and since field burning of agricultural residues does not occur in Luxembourg (see Section 5.7), crop production data are described in this section on the methodology for agricultural soil emission estimates.

Crop production by categories is presented in Table 5-31. It is mainly the various aggregated categories that are used to estimate some direct soil nitrous oxide emissions. The agricultural area, cropland as well as grassland, is also included.

5.5.3.1.3 Sewage sludge spreading on fields

Under IPCC Sub-category 3D – Other Direct Soil Emissions, first estimates are provided for the use of sewage sludge in agriculture as a complement/replacement to nitrogenous, phosphate or potassic fertilizers. These estimates cover sewage sludge spreading on fields and, for 2000 onwards, spreading of compost made, among other components, out of sewage sludge. The latter is the result of the starting of a project called "Soil-Concept" that aims at reducing direct spreading of sludge on agricultural lands thanks to the spreading of compost which is less harmful to the environment.[127]

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127 See http://www.soil-concept.lu/.

Sewage sludge data used in the inventory are derived from:

- estimates for the total sewage sludge produced in the various wastewater treatment plant (*WWTP*) of the country. These estimates have been prepared by the MDDI-AEV (Environment Agency) with some corrections performed by the MDDI-DEV for the years 2000 to 2004;
- annual reports on sewage sludge that are regularly issued since 2003.[128] These reports are based on a questionnaire sent to WWTPs with at least 2000 inhabitants-eq., hence not all the WWTPs are interrogated. The questionnaire requests, among other things, to indicate the destination and the use of the sludge, both in Luxembourg and abroad: agriculture – what matters here –, composting – information used for IPCC Category 3D – and incineration – an operation done in Germany.
- Consequently, activity data used as basis for calculating sewage sludge spreading related N_2O emissions should be associated with an expert judgment.

128 See http://www.environnement.public.lu/dechets/statistiques_indicateurs/index.html under "*Statistiques sur les boues d'épuration" /* "*Klärschlammstatistik Luxemburg*".

Table 5-31 – Crop production (t) and agricultural area (ha): 1990-2015

Years	Maize	Winter wheat	Spring wheat	Barley	Oats	Rye	Potato	Other cereals	N-fixating crops	Other crops	Agricultural area
1990	NE	39657	3854	69611	18757	2366	22963	13194	1360	5348	126298
1991	NE	41290	3011	73480	19481	2218	19499	16896	1648	6648	125469
1992	NE	43323	2801	70386	17237	1923	26866	16671	2184	2310	125742
1993	NE	45234	3300	68059	17109	1826	25654	16352	2174	4500	127215
1994	NE	42892	2351	59882	12369	1519	17859	14617	1836	3730	126765
1995	NE	50961	1784	62822	12150	1703	22857	18165	1380	6795	126865
1996	NE	62184	2215	72456	13278	2326	20244	23044	1917	7632	126370
1997	2285	55301	2076	68627	13247	2715	22820	17756	1531	7865	126629
1998	4293	57911	2162	63203	11693	4051	22313	23904	1420	9186	127136
1999	3112	40331	6048	67775	12246	3535	25704	20748	2307	13568	127405
2000	132276	58380	1893	53533	9217	3603	27858	23253	1235	8370	127643
2001	162267	49506	3595	53566	7799	4803	22770	19778	2277	8780	127942
2002	149937	67629	2642	51823	10219	7470	20105	25303	2327	12522	128114
2003	180870	65534	2303	55330	11414	4606	18329	22239	2146	12535	128157
2004	192396	76702	2106	52761	9458	7921	22244	25254	1729	16526	128073
2005	195425	67577	3166	52853	7734	5715	19329	20462	1488	14704	129128
2006	162638	71968	2280	50061	6650	6156	16449	21117	1185	16250	128875
2007	207258	67644	1620	44640	5634	6953	19968	18536	824	18302	130884
2008	197686	92825	2147	52450	6241	8727	21757	22771	765	16425	130421
2009	220487	86040	3006	54398	7197	6924	20044	26687	1206	18132	130762
2010	184220	80367	1731	43003	4789	5118	19531	26685	973	15895	131106
2011	179798	73048	2274	38451	4035	4189	19679	23742	623	15574	131330
2012	201364	75535	2091	37896	4749	5225	20610	24743	459	15338	131492
2013	190561	86433	3096	42485	5535	4766	17540	27284	933	15259	131043
2014	235082	70727	5416	45962	5476	5591	18979	31919	1047	15705	130805
2015	178660	80282	3277	45790	5196	5321	13859	27981	1611	14011	130950

Sources: SER.

5.5.3.2 Emission factors

For estimating agricultural soils nitrous oxide emissions, as indicated above, Tier 1 methods have been applied. Table 5-32 specifies, for each source category, which method has been used for estimating the emissions as well as the corresponding EF type.

Table 5-32 – Method and type of EF used in the inventory

Agricultural soils sub-category	Estimation method	EF	Comments
3D – Direct Soil Emissions – Synthetic Fertilizers	T1	D	*Equation 11.1 – 2006 IPCC Guidelines*
3D – Direct Soil Emissions – Animal Manure Applied to Soils	T1	D	
3D – Direct Soil Emissions – Crop Residue	T1	D	*Equation 11.6 – 2006 IPCC Guidelines*
3D – Direct Soil Emissions – cultivation of histosols	NO	NO	
3D – Direct Soil Emissions – Other – Sewage Sludge Spreading	T1	D	*Equation 11.3 – 2006 IPCC Guidelines*
3D – Pasture Manure	T1	D	*Equation 11.4 – 2006 IPCC Guidelines*
3D – Indirect Emissions – Atmospheric Deposition	T1	D	*Equation 11.9 + 11.10 – 2006 IPCC Guidelines*
3D – Indirect Emissions – Nitrogen Leaching & Run-off	T1	D	

Source: SER.

Abbreviations: T1, T1a & T1b = Tier 1 methods; D = IPCC Default

5.5.3.2.1 Direct Soil Emissions – Emissions from N fertilizer input (3D)

For synthetic fertilizer, manure and compost application to soils, N_2O emissions have been estimated using equation 11.1 from 2006 IPCC GLs:

$$N_2O - N_{N\ inputs} = [(F_{SN} + F_{ON} + F_{CR} + F_{SOM}) * EF_1] * 44/28$$

with:

$N_2O - N_{N\ inputs}$: annual direct emissions from N input in kg N_2O-N

F_{SN} : annual amount of synthetic N fertiliser in kg N

F_{ON}: annual amount of organic N in kg N (eq. 11.3 IPCC 2006 GLs)

F_{CR} : annual amount of N in crop residues in kg N (eq. 11.6 IPCC 2006 GLs)

F_{SOM} : annual amount of N in mineral soils (eq. 11.8 IPCC 2006 GLs, "NO")

EF_1 : emission factor for N inputs (table 11.1 IPCC 2006 GLs)

5.5.3.2.2 Direct Soil Emissions – Crop residues (3D)

To determine the mass of N in crop residues, an equation similar to 11.6 – 2006 IPCC Guidelines has been used:

$$F_{CR} = \sum_{T}\{(Crop_T * R_{AG(T)} * N_{AG(T)}) + (Crop_T * R_{BG(T)} * N_{BG(T)})\}$$

with:

$Crop_T$ in t/year

$R_{AG(T)}$: ratio above ground residues (see comments on eq. 11.6 – 2006 IPCC GLs)

$N_{AG(T)}$: N content in above ground residues in kg N (see eq. 11.6 – 2006 IPCC GLs)

$R_{BG(T)}$: ratio below ground residues (see comments on eq. 11.6 – 2006 IPCC GLs)

$N_{BG(T)}$: N content in below ground residues in kg N (see eq. 11.6 – 2006 IPCC GLs)

5.5.3.2.3 Direct soil emissions - PRP Manure (3D)

For Nex on PRP, the amount of urine and dung N deposited by grazing animals has been estimated using equation 11.5 – 2006 IPCC Guidelines. The emission calculation has been presented in Section *5.3.2*. The used formula is:

$$F_{PRP} = \sum_{T}[(N_T * N_{ex}) * MS_{(T,PRP)}]$$

with Nex = the total nitrogen excretion per animal category kg N/(head*year)

N_T = number of head per livestock category

$MS_{(T, PRP)}$ = proportion of animals in pasture system (%)

For livestock N excreted and deposited onto soil during grazing, N_2O emissions have been estimated using equation 11.1 from 2006 IPCC GLs:

$$N_2O - N = F_{PRP} * EF_{PRP}$$

5.5.3.2.4 Indirect Soil Emissions – Atmospheric Deposition (3D)

For volatized nitrogen from fertilizers, animal manures and other, N_2O emissions have been estimated using equation 11.9 – IPCC 2006 GLs:

$$N_2O_{ATD} - N = \{(F_{SN} * Frac_{GASF}) + [(F_{ON} + F_{PRP}) * Frac_{GASM}]\} * EF_4 * 44/28$$

with N_2O_{ATD}-N in kg N_2O-N/year

F_{SN} : annual amount of synthetic fertilizer in kg N/year

F_{ON} : annual amount of animal manure, sewage sludge, compost in kg N/year

F_{PRP} : annual amount of dung and urine deposited during grazing in kg N/year

EF_4 : emission factor for N_2O emission from atmospheric deposition of N

fractions used for calculating N_2O_{ATD}-N = $Frac_{GASF}$ & $Frac_{GASM}$ (see Table 5-29)

5.5.3.2.5 Indirect Soil Emissions – Nitrogen Leaching & Run-off (3D)

For nitrogen from fertilizers, animal manures and other that is lost through leaching and run-off, N_2O emissions have been estimated using equation 11.10 – IPCC 2006 GLs:

$$N_2O_L - N = (F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM}) * Frac_{LEACH} * EF_5 * 44/28$$

with N_2O_L-N in kg N_2O-N/year

EF_5 in kg N_2O-N/kg N extracted from table 11.3 – 2006 IPCC-GLs

fraction used for calculating $N_2O\text{-}N_{(L\text{-}SOIL)}$ = $Frac_{LEACH}$ (see Table 6-29)

5.5.3.2.6 Nitrous oxide EFs for Agricultural Soils (3D)

Table 5-33 summarizes the default EFs used for estimating nitrous oxide emissions from agricultural soils.

Table 5-33 – N_2O default EFs for IPCC Category 3D – Agricultural Soils

Agricultural soils sub-category	Default EF	Value	Source
3D– Direct Soil Emissions – N addition	EF_1	0.01 kg N_2O-N/kg N	table 11.1 – 2006 IPCC-GLs
3D – Direct Soil Emissions – for cattle, poultry and pigs	$EF_{3PRP,CPP}$	0.02 kg N_2O-N/kg N	
3D – Direct Soil Emissions – for sheep and other animals	$EF_{3PRP,SO}$	0.01 kg N_2O-N/kg N	
3D – Indirect Soil Emissions – atmospheric deposition	EF_4	0.01 kg N2O-N / kg NH_3-N + NO_X-N	table 11.3 – 2006 IPCC-GLs
3D – Indirect Soil Emissions – Leaching	EF_5	0.0075 kg N_2O-N / kg N	

5.5.4 Category-specific recalculations including changes made in response to the review process

No recalculations were made.

5.5.5 Category specific uncertainty

Uncertainties associated with agricultural statistics in category 3D are estimated by the sector expert. Table 5-34 gives an overview of the uncertainties attributed to emission factors and activity data.

Table 5-34 - Uncertainties used in category 3D

Category	Description	Uncertainty	Source
frac.los	amount of managed manure nitrogen for livestock category that is lost in the manure management system	90%	tab 10.32 p 10.67
f.sn	activity data on synthetic fertiliser	10%	estimation by sector expert
f.sew	activity data on sewage sludge	10%	estimation by sector expert
f.comp	activity data on compost	10%	estimation by sector expert
f.cr	activity data crop residues	20%	estimation by sector expert
f.ooa	activity data other organic matter	10%	estimation by sector expert
EF N_2O	N_2O emission factor for soils	250%	estimation by sector expert (tab. 11.1 p 11.11)
EF prp	emission factor N deposited by grazing animals on pasture, range and paddock	200%	tab 11.1 p 11.11
EF 4	N volatilisation and re-deposition	50%	tab 11.3 p 11.11
M.lime	activity data liming	20%	estimation by sector expert
M.dolomite	activity data dolomite	20%	estimation by sector expert
M.urea	activity data urea	20%	estimation by sector expert
EF lime	CO2 emission factor liming	50%	estimation by sector expert
EF dolomite	CO2 emission factor dolomite	50%	estimation by sector expert
EF urea	CO2 emission factor urea	50%	see 11.4.1 p 11.32

5.5.6 Category-specific QA/QC and verification

Consistency and completeness checks have been performed before starting the calculations, as well as during the work process. Also the tools embedded in CRF Reporter were of great utility. The plausibility of the estimates, as well as the calculation methods were extensively discussed by the sector experts from SER and ASTA.

5.5.7 Planned improvement

SER will try to improve and complete the time series of maize production in crop production activity data Table 5-31.

5.6 Prescribed Burning of Savannahs (IPCC Source Category 3.E)

This source category does not exist in Luxembourg.

5.7 Field Burning of Agricultural Residues (IPCC Source Category 3.F)

Article 17, paragraph 2, indent b), of the Law of 19 January 2004 relating to the preservation of the nature and of the natural resources[129] forbids clearing and burning[130] of fields, meadows, grasslands, roadsides, forests between the 1st of March and the 30th of September. According to the law, the clearing and burning of agricultural residues (such as straw) is not strictly forbidden. However, for economic reasons (residues can be used as litter, as feeding stuff for animals or can be sold), field burning is not practiced in Luxembourg and, therefore, emission estimates have been recorded as not occurring (notation key NO) in the inventory.

5.8 Emissions from Liming (IPCC source Category 3G)

This section describes the estimation of carbon dioxide emissions resulting from liming in agricultural soils. Liming is used to reduce soil acidity and improve plant growth in managed systems, particularly agricultural lands and managed forests. In 2015, this source category was responsible for 0.9% of the total GHG emissions from the agriculture sector and represented 0.06% of the total GHG emissions in CO2e (excluding LULUCF).

5.8.1 Source category description

This category consists of emissions resulting from the agricultural use of

- Limestone
- Dolomite

CO_2 emissions from soils due to liming are provisional as there is no data on dolomite usage available. The only data available is of lower quality and represents the usage of limestone in agriculture. Table 5-35 shows the volatile emission trends. Unfortunately no data update on limestone usage has been provided since 2013.

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129 See http://www.legilux.public.lu/leg/a/archives/2004/0010/a010.pdf#page=2.

130 "essartement" in French.

Table 5-35 - CO_2 emission trends for IPCC Category 3G – Liming: 1990-2015 (Gg)

years	Emissions from liming
1990	0,590
1991	0,708
1992	0,827
1993	0,946
1994	1,373
1995	1,122
1996	0,990
1997	1,465
1998	2,022
1999	1,126
2000	1,888
2001	2,288
2002	2,904
2003	2,816
2004	2,420
2005	3,907
2006	3,049
2007	3,080
2008	2,860
2009	4,074
2010	4,180
2011	4,884
2012	5,060
2013	5,808
2014	5,808
2015	5,808
Trend '90-'15	**885%**

5.8.2 Methodological issues

Tier 1 method has been used to estimate the emissions resulting from liming.

5.8.2.1 Activity data

Table 5-36 shows the activity data used for the emission estimations. The time series is not homogenous and very volatile.

Table 5-36 - Activity data (t) for IPCC Category 3G Liming: 1990-2015

Years	Lime
1990	1340
1991	1610
1992	1880
1993	2150
1994	3120
1995	2550
1996	2250
1997	3330
1998	4595
1999	2560
2000	4290
2001	5200
2002	6600
2003	6400
2004	5500
2005	8880
2006	6930
2007	7000
2008	6500
2009	9260
2010	9500
2011	11100
2012	11500
2013	13200
2014	13200
2015	13200

5.8.2.2 Emission factors

The IPCC default emission factors very used, i.e. 0.12 t CO_2 /t limestone.

5.8.3 Category specific recalculations

None.

5.8.4 Category specific uncertainty

Uncertainty in these data is high but also difficult to estimate due to the lack of data sources. Only rough estimates of limestone consumption are available, sources for historical data are non-existent. Uncertainties are estimated to be 20% for activity data and 50% for emission factors.

5.8.5 Category-specific QA/QC and verification

Consistency and completeness checks have been performed before starting the calculations, as well as during the work process. The plausibility of the estimates, as well as the calculation methods were extensively discussed by the sector experts from SER and ASTA.

5.8.6 Planned improvement

A limestone inventory having limestone vendors as data sources is envisaged to enhance future quality of data, however historical data is difficult to be validated or corrected. Data updates for the years 2014 and 2015 will be provided.

5.9 Emissions from urea application (IPCC Source Category 3H)

Activity data on urea application were provided by SER for the years 2013-2015. After "extrapolation" of these data back to 1990 by the NIC during review process, a full time series of activity data were created. These data are included in the CRF tables but no emissions were calculated as a result of the non-significance of the emissions and in order to prevent adding incoherencies to the emissions inventory due to the use of "extrapolation" technique over a very long period of time (cf. IPCC 2006 GLs vol.1 chap.5 5.3.3.4 Trend extrapolation p. 5.12). Uncertainties for these activity data were not estimated as no reliable evaluation of forecast accuracy, or, in this case, "backcast" accuracy of 20 years of trend extrapolation can be made.

5.10 Other carbon containing fertilizer and others (IPCC Source Category 3I an 3J)

These source categories are not used in Luxembourg's GHG inventory.

5.11 Uncertainty assessment of the Agriculture sector

Uncertainty assessment for GHG emissions have been calculated using approach 1 in chapter 3 of the General Guidance Reporting of the 2006 IPCC GLs: error propagation. Calculations are based on the generalized formula:

For any general function F of one or more observables X, Y, …,

$$F = f(X, Y, \ldots)$$

the uncertainty of F, noted δF, is obtained by taking the square root of the sum of squares of the partial derivatives of F, noted ∂F, with respect to each variable X,Y,…, multiplied by the uncertainty in that variable δX, δY,...

$$\delta F = \sqrt{\left(\frac{\partial \mathrm{F}}{\partial \mathrm{X}} * \delta X\right)^2 + \left(\frac{\partial \mathrm{F}}{\partial Y} * \delta Y\right)^2 + \cdots}$$

The resulting uncertainties for the whole time series of emissions for each GHG respectively from 1990 to 2015 are shown in Table 5-37 in absolute as well as relative terms. The low uncertainties for CH_4 result from the low uncertainties in activity data and the low uncertainties in emission factors. The high uncertainties of N_2O-emissions are mainly due to the high uncertainties in emission factors of N_2O by soils, which is not a surprise as N_2O emissions from soils vary heavily according to the bio-physiological properties of the type of soil on which emissions are measured as well as the surrounding temperatures.

Table 5-37 - Absolute (Gg) and relative (%) uncertainties by GHG 1990-2015

years	CH_4 absolute	CH_4 relative	N_2O absolute	N_2O relative	CO_2 absolute	CO_2 relative
1990	0,620	3%	1,074	130%	0,318	54%
1991	0,598	3%	1,129	132%	0,381	54%
1992	0,588	3%	1,050	130%	0,445	54%
1993	0,603	3%	1,010	129%	0,509	54%
1994	0,684	4%	0,990	130%	0,739	54%
1995	0,697	4%	1,010	128%	0,604	54%
1996	0,694	4%	1,002	127%	0,533	54%
1997	0,682	4%	0,985	127%	0,789	54%
1998	0,680	4%	0,993	128%	1,089	54%
1999	0,726	4%	1,002	128%	0,607	54%
2000	0,699	4%	0,988	128%	1,017	54%
2001	0,706	4%	0,887	124%	1,232	54%
2002	0,699	4%	0,903	126%	1,564	54%
2003	0,664	4%	0,789	121%	1,516	54%
2004	0,653	4%	0,917	128%	1,303	54%
2005	0,540	3%	0,837	124%	2,104	54%
2006	0,519	3%	0,828	125%	1,642	54%
2007	0,530	3%	0,812	122%	1,659	54%
2008	0,539	3%	0,820	122%	1,540	54%
2009	0,529	3%	0,823	122%	2,194	54%
2010	0,566	3%	0,827	122%	2,251	54%
2011	0,678	4%	0,877	125%	2,630	54%
2012	0,646	4%	0,827	124%	2,725	54%
2013	0,678	4%	0,845	124%	3,128	54%
2014	0,708	4%	0,805	121%	3,128	54%
2015	0,751	4%	0,806	121%	3,128	54%

Source: SER.

6 Land Use, Land-Use Change and Forestry (CRF sector 4)

Chapter 6 includes information on and description of methodologies used for estimating GHG emissions as well as references to activity data and emission factors reported under CRF Sector 4 – Land Use, Land-use Change and Forestry – *i.e.* LULUCF – for the period 1990 to 2015.

6.1 Sector Overview

In 2015, Sector *4 – Land Use, Land Use Change and Forestry* was a net sink in Luxembourg (Table 1-1). Net removals from the LULUCF sector amounted to 404.9 Gg CO_2e. Since 1990, net emissions have decreased by -1073.8 per cent (the sector was a source of net emissions in 1990 (48.33 Gg CO_2e) and a source of net removals in 2015). The key driver for the fall in emissions is the ongoing increase in net removals in forest land remaining forest land following the recovery from the major disturbance events in the early 1990s. Within the sectors, forest land and grassland resulted in net removals (-479.66 Gg CO_2e and -46.64 Gg CO_2e, respectively). All other categories resulted in net emissions: the largest source of emissions was from settlements (72.62 Gg CO_2e), followed by cropland (42.50 Gg CO_2e), wetlands (5.96 Gg CO_2e) and other land (0.29 Gg CO_2e).

Table 6-1 - Emissions and Removals from CRF Sector 4 - LULUCF

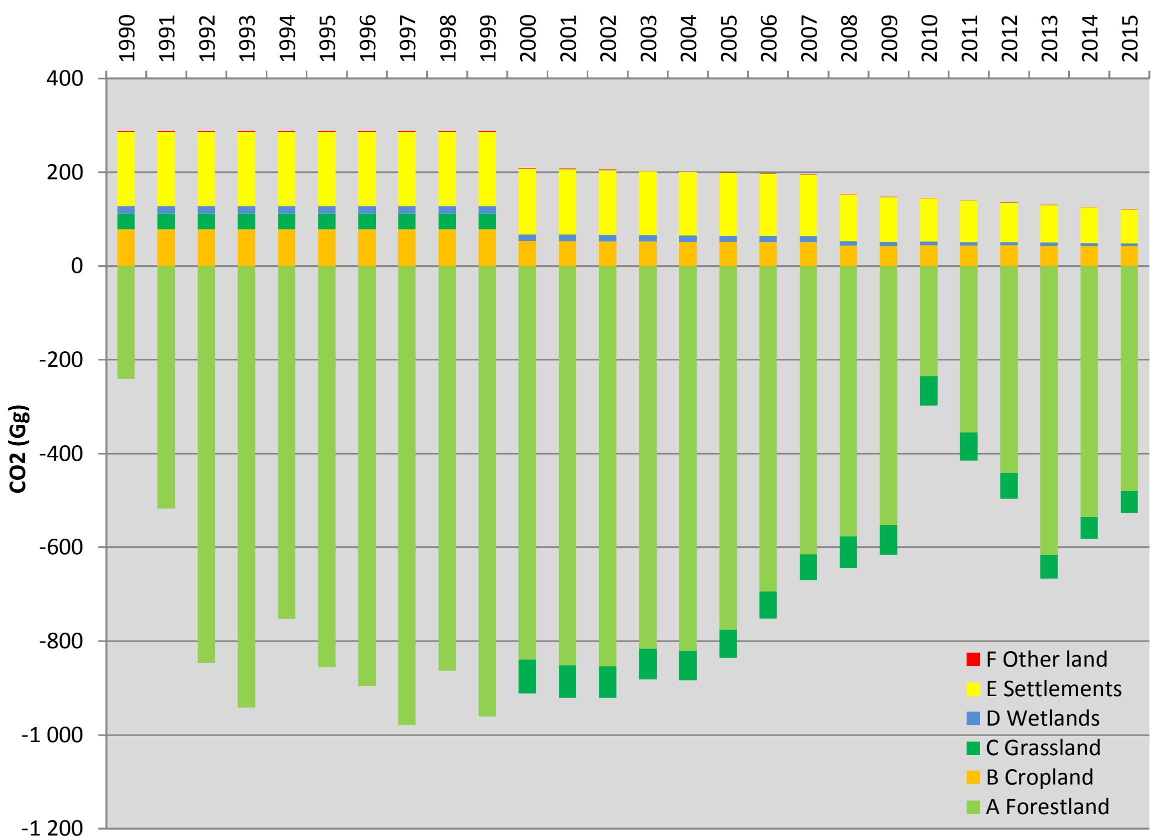
4 - Land Use, Land Use Change & Forestry *Greenhouse gas emissions/removals (Gg CO_2 e)*							
Year	**4 Total**	**A Forestland**	**B Cropland**	**C Grassland**	**D Wetlands**	**E Settlements**	**F Other land**
1990	*48.33*	*- 239.80*	*78.88*	*32.90*	*16.45*	*158.12*	*1.78*
1991	*- 228.91*	*- 517.04*	*78.88*	*32.90*	*16.45*	*158.12*	*1.78*
1992	*- 558.08*	*- 846.22*	*78.88*	*32.90*	*16.45*	*158.12*	*1.78*
1993	*- 653.15*	*- 941.29*	*78.88*	*32.90*	*16.45*	*158.12*	*1.78*
1994	*- 463.96*	*- 752.10*	*78.88*	*32.90*	*16.45*	*158.12*	*1.78*
1995	*- 567.04*	*- 855.18*	*78.88*	*32.90*	*16.45*	*158.12*	*1.78*
1996	*- 607.46*	*- 895.60*	*78.88*	*32.90*	*16.45*	*158.12*	*1.78*
1997	*- 690.19*	*- 978.33*	*78.88*	*32.90*	*16.45*	*158.12*	*1.78*
1998	*- 574.62*	*- 862.75*	*78.88*	*32.90*	*16.45*	*158.12*	*1.78*
1999	*- 672.33*	*- 960.46*	*78.88*	*32.90*	*16.45*	*158.12*	*1.78*
2000	*- 702.01*	*- 839.18*	*53.67*	*- 72.27*	*14.10*	*140.67*	*1.00*
2001	*- 713.71*	*- 851.37*	*53.27*	*- 69.80*	*13.93*	*139.30*	*0.96*
2002	*- 715.10*	*- 853.26*	*52.88*	*- 67.34*	*13.76*	*137.94*	*0.92*
2003	*- 677.74*	*- 816.38*	*52.49*	*- 64.88*	*13.59*	*136.57*	*0.88*
2004	*- 681.49*	*- 820.63*	*52.10*	*- 62.41*	*13.42*	*135.20*	*0.84*
2005	*- 635.91*	*- 775.54*	*51.70*	*- 59.95*	*13.25*	*133.83*	*0.80*
2006	*- 553.84*	*- 693.96*	*51.31*	*- 57.49*	*13.08*	*132.47*	*0.76*
2007	*- 473.93*	*- 614.54*	*50.92*	*- 55.02*	*12.91*	*131.10*	*0.72*
2008	*- 490.62*	*- 576.54*	*43.45*	*- 67.29*	*9.97*	*99.18*	*0.61*
2009	*- 467.90*	*- 552.46*	*42.84*	*- 63.63*	*9.39*	*95.39*	*0.56*
2010	*- 152.85*	*- 234.52*	*43.90*	*- 63.16*	*8.82*	*91.59*	*0.52*
2011	*- 274.89*	*- 355.02*	*43.28*	*- 59.66*	*8.25*	*87.80*	*0.47*
2012	*- 360.60*	*- 441.43*	*43.59*	*- 54.87*	*7.68*	*84.00*	*0.42*
2013	*- 535.93*	*- 615.66*	*42.89*	*- 50.84*	*7.10*	*80.21*	*0.38*
2014	*- 456.25*	*- 535.99*	*42.38*	*- 45.92*	*6.53*	*76.41*	*0.33*
2015	*- 404.94*	*- 479.66*	*42.50*	*- 46.64*	*5.96*	*72.62*	*0.29*
Trend 1990-2015	*-1037.79%*	*0.02%*	*-146.13%*	*-341.74%*	*-163.77%*	*-154.08%*	*-183.89%*
Trend 2013-2015	*-24.44%*	*-22.09%*	*-0.91%*	*-8.27%*	*-16.11%*	*-9.46%*	*-24.22%*

6.1.1 Emission Trends

In 2015, removals from category forest land corresponded to 4.1% of total GHG in Luxembourg (incl. LULUCF). The net removals have increased from the base year to 2015, mainly due to the fact that in 1990 forestland was less of a carbon sink due to the heavy windfall during the winter 1990/1991, but also due to an increase of the carbon stock in forest land in the years after (Figure 1-1).

The net carbon stock changes in forest biomass (sector 4.A.1) have a major impact on the overall results in sector 4. These changes vary considerable between single years mainly due to fluctuating harvest rates. The harvest rates in their turn are influenced by timber demand and prices, insect infestation or wind throws.

Figure 6-1 - Emissions and Removals from CRF Sector 4 - LULUCF



6.1.2 Key categories

The methodology and results of the key category analysis are presented in Chapter 1. Table 1-2 presents the key categories of IPCC category *4 - LULUCF*.

Table 6-2 - Key categories of IPCC Sector 4 - LULUCF

4 - Land Use, Land-Use Change and Forestry						
Key sources						
IPCC Category	**Category Name**	**GHG**	**LA excl. LULUCF**	**LA incl. LULUCF**	**TA excl. LULUCF**	**TA incl. LULUCF**
4A1	Forest Land remaining Forest Land	CO_2	*NA*	92-09, 11-15	*NA*	
4A2	Land Converted to Forest Land	CO_2	*NA*	90, 10	*NA*	

Source: Environment Agency

Notes: LA = Level Assessement (Tier 1) including respectively exluding LULUCF
TA = Trend Assessement 2015 (Tier 1) including respectively exluding LULUCF

6.1.3 Methodology

The territory of Luxembourg has an area of 2 586 km². In 1990, 90.5% of that area was covered by agriculturally used areas and forests, 8.6% were covered by buildings and roads. The remaining areas were covered by water and other land (0.8%). In 2015, the respective areas were 89.6%, 9.9% and 0.5%. Thus, Luxembourg has some 96 148 ha of forests, some 135 486 ha of agriculturally used land, and some 25 678 ha covered by buildings and roads. Rivers, lakes, wetlands and other lands cover a surface of some 1 233 ha.

Meteorologically, Luxembourg is situated in an area with temperate maritime climate, with an annual average temperature of 10.4°C (Statec, 2016) (year 2016), approximately.

6.1.3.1 Information on approaches used for representing land areas and on land use databases used for the inventory preparation

Before deciding which activity data would be used, an inventory of the available activity data sources for Luxembourg was made. Until 2009, the only datasets available in Luxembourg for different time periods and covering all the land uses in the whole country was the CORINE Land cover database. It is available for the reference year 1989 and has been updated in 2000 and 2007. Land-use and land-use change areas of submissions until 2009 were estimated on the basis of the CORINE Landcover database.

The base data used since submission 2010 under the UNFCCC as well as under the Kyoto Protocol is the so-called OBS map data "Occupation Biophysique du Sol". This is a detailed land use / land cover map in digital format covering the entire territory of Luxembourg. Three versions of the OBS map data set exist. The first OBS data set, the OBS89, was collected in the field over several years and published in 1989 by the Environment Ministry. The second data set for the year 1999, the OBS99, was collected based on aerial colour infra-red ortho-photos and some field surveying, the third set, covering the year 2007, is the OBS07, which is an update of the OBS99 using very high resolution satellite images (1m pixel size) of the US commercial Earth observation satellite IKONOS. The latest dataset on land use in Luxembourg, covering the year 2012, is the LU12, which is based on satellite images from the RapidEye (RE) space segment, which is composed of five sun-synchronous Earth observation satellites providing large area, multi-spectral images with frequent revisits in high resolution (5m).

6.1.3.2 Land-use definitions and the classification systems used and their correspondence to the LULUCF categories (*e.g.* land use and land-use change matrix)

The land use classification system used is in accordance with the 2006 IPCC Good Practice Guidance on LULUCF. The categories are defined as presented in Table 1-3 .

The OBS categories – that are different for OBS89 and OBS99/07 – have been assigned to the LULUCF categories, as defined in Table 1-3 , according to the following matching tables:

Table 1-4 for OB89 to LULUCF and Table 1-5 for OBS99/07 to LULUCF.

Table 6-3 – LULUCF Nomenclature

Land Use Class	Definition
ForestLand	All forest and wooded land according to the FAO TBRA2000 definition: • Minimum land area: 0.5 ha • tree crown cover >= 10 % • tree height >= 5 m. In the geodata set, Forest land has been sub-divided into the forest types as defined below.
Conifers:	Including all forest land with > 10 % crown cover and on which more than 75 percent of the tree crown cover consists of coniferous species.
Deciduous:	Including all forest land with > 10 % crown cover and on which more than 75 percent of the tree crown cover consists of broadleaved species
Mixed (coniferous and deciduous):	with > 10 % crown cover and less than 75 % crown cover of one class.
Annual Cropland	Includes agro-forestry systems where tree cover falls below the level used in the forest categories (IPCC GPG definition) with the following specifications: land on which different crops are grown in a yearly changed rhythm including artificial meadows (not permanent) including land temporarily set aside
Permanent Cropland	Includes agro-forestry systems where tree cover falls below the level used in the forest categories (IPCC GPG definition) with the following specifications: land on which different crops are grown in a permanent manner, *i.e.* not changing in a yearly rhythm
Grassland	All grassland that is not considered as cropland including systems with vegetation or tree cover below the density used in the forest category. This includes all grassland from wild lands, recreational areas as well as agricultural systems. (IPCC GPG definition).
Settlements	All developed land, including transportation and any size of human settlement unless already included under other categories.(IPCC GPG definition)
Wetland	Land that is covered or saturated by water for all or part of the year (*e.g.* peat land) and that does not fall into other categories.
Water	Land that is covered by water for all the year and that does not fall into other categories. This includes reservoirs. (IPCC GPG definition)
Other land	This category includes bare soil, rock, ice, and all unmanaged land areas that do not fall into any of the other five categories. It allows the total of identified land areas to match the national area, where data are available.

Table 6-4 –OBS89 - LULUCF matching table

OBS89 Nomenclature (Part 1/3)						
Acronym	**Code**	**Original in French**	**translated into German**	**LULUCF_v7**	**Forest Types_v7**	**Forest Areas v7**
	31	forets	Wald			Forest Area
P	312	forets de coniferes	Nadelwald	Coniferous Forest	Coniferous Forest	Forest Area
Pe	3121	epiceas, sapins	Fichte, Tannen	Coniferous Forest	Coniferous Forest	Forest Area
Pm	3122	pins, mezeles	Kiefern, Lärchen	Coniferous Forest	Coniferous Forest	Forest Area
Pr	3123	autres resineux	Other Land Nadelbaeume	Coniferous Forest	Coniferous Forest	Forest Area
	311	forets de feuillus	Laubwald	Deciduous Forest	Deciduous Forest	Forest Area
F/Q	3111	forets acidophiles	Saure Wälder	Deciduous Forest	Deciduous Forest	Forest Area
Qb	31111	chenaie acidophile tres pauvre	artenarmer saurer Eichenwald	Deciduous Forest	Deciduous Forest	Forest Area
Fs	31112	hetraie et chenaie-hetraie acidophile	saurer Buchen und Eichen-Buchenwald	Deciduous Forest	Deciduous Forest	Forest Area
Qs	31113	chenaie acidophile	saurer Eichenwald	Deciduous Forest	Deciduous Forest	Forest Area
Fl	31114	hetraie a luzule blanche	Buchen mit weissen Luzernen	Deciduous Forest	Deciduous Forest	Forest Area
Ql	31115	chenaie a luzule blanche	Eichenwald mit Luzernen	Deciduous Forest	Deciduous Forest	Forest Area
Ff	31116	hetraie a grande fetuque	Buchenwald mit hohen Graesern	Deciduous Forest	Deciduous Forest	Forest Area
Qx	31117	chenaie a charmes xerophile sur schistes et gres	besondere trockenheitsliebende Eichenart auf Schiefer und Sandstein	Deciduous Forest	Deciduous Forest	Forest Area
F/Q	3112	forets neutroclines a mull	Wälder auf neutralen Bodenverhältnissen	Deciduous Forest	Deciduous Forest	Forest Area
Fm	31121	hetraie a melique et asperule	Buchenwald mit irgendeinem bestimmten Unterwuchs	Deciduous Forest	Deciduous Forest	Forest Area
Qa	31122	chenaie a charmes humide	besondere Eichenart auf feuchten Standorten	Deciduous Forest	Deciduous Forest	Forest Area
Qm	31123	chenaie-charmaie a melique et asperule	besondere Eichenart mit irgendeinem Unterwuchs	Deciduous Forest	Deciduous Forest	Forest Area
F/Q	3113	forets basiclines	Wälder auf basischen Bodenverhältnissen	Deciduous Forest	Deciduous Forest	Forest Area
Fk	31131	hetraie calcicole	Buchenwald auf kalkhaltigem Substrat	Deciduous Forest	Deciduous Forest	Forest Area
Qk	31132	chenaie a charmes xerophile	trockenheitsliebende besondere Eichenart	Deciduous Forest	Deciduous Forest	Forest Area
R	3114	forets ruderales	Schuttwälder	Deciduous Forest	Deciduous Forest	Forest Area
Ru	31141	ormaie ruderale	Ulmenwald in Aufschuettungen	Deciduous Forest	Deciduous Forest	Forest Area
P	3115	plantation de feuillus	Laubwald Anpflanzung	Deciduous Forest	Deciduous Forest	Forest Area
Ps	31151	peupleraie en site sec	Pappelwald in trockenen Gebieten	Deciduous Forest	Deciduous Forest	Forest Area
Ph	31152	peupleraie en site humide	Pappelwald in feuchten Gebieten	Deciduous Forest	Deciduous Forest	Forest Area
Pf	31153	plantation d'autres essences feuillus	Anpflanzungen Other Landr Laubbaeume	Deciduous Forest	Deciduous Forest	Forest Area
E	3116	forets de ravins	Schluchtwälder	Deciduous Forest	Deciduous Forest	Forest Area
Ek	31161	foret de ravin sur substrat calcaire	Schluchtwald auf kalkhaltigem Substrat	Deciduous Forest	Deciduous Forest	Forest Area
Es	31162	foret de ravin sur substrat siliceux	Schluchtwald auf silikatischem Substrat	Deciduous Forest	Deciduous Forest	Forest Area
V	3117	forets alluviales sur sols mineraux	Auewald auf mineralischem Boden	Deciduous Forest	Deciduous Forest	Forest Area
Va	31171	ormaie-frenaie alluviale	Ulmen-Eschenwald in Flusssedimenten	Deciduous Forest	Deciduous Forest	Forest Area
Vb	31172	aulnaie-frenaie alluviale mesotrophe	Erlen-Eschenwaelder in Flusssedimenten	Deciduous Forest	Deciduous Forest	Forest Area
Vn	31173	aulnaie alluviale nitrophile	Erlenwaelder in nitratreichen Flusssedimenten	Deciduous Forest	Deciduous Forest	Forest Area
Vc	31174	aulnaie-frenaie des sources et ruisseaux	Erlen-Eschenwaelder in Quellgebieten und an Rinnsalen	Deciduous Forest	Deciduous Forest	Forest Area
V	3118	forets marecageuses a sedimentation organique	Moorbruchwälder	Deciduous Forest	Deciduous Forest	Forest Area
Vm	31181	aulnaie mesotrophe a laiches	Erlenwaelder mit Seggen	Deciduous Forest	Deciduous Forest	Forest Area
Vx	31182	boulaie marcageuse	sumpfiger Birkenwald	Deciduous Forest	Deciduous Forest	Forest Area
	323	vegetations sclerophylles	Holzartiges Gebüsch	Deciduous Forest	Deciduous Forest	Forest Area
S	324	forets et vegetation arbustive en mutation	Wald und Gehölz im übergang	Deciduous Forest	Deciduous Forest	Forest Area
	3241	fourres en sites secs	Wälder auf trockenen Standorten	Deciduous Forest	Deciduous Forest	Forest Area
Sp	32411	fourre d'epineux	dorniges Dickicht	Deciduous Forest	Deciduous Forest	Forest Area
Sk	32412	fourre calcaire	Dickicht auf kalkhaltigem Untergrund	Deciduous Forest	Deciduous Forest	Forest Area
Sx	32413	fourre de buis	Buchsbaumdickicht	Deciduous Forest	Deciduous Forest	Forest Area
Se	32414	vegetation des coupes forestiere	Vegetation der Waldrodungsflaechen	Deciduous Forest	Deciduous Forest	Forest Area - no trees
Sz	32415	recrus divers	verschiedene Pionierpflanzen nach Rodung	Deciduous Forest	Deciduous Forest	Forest Area - no trees
	3242	fourres en sites humides	Wälder auf feuchten Standorten	Deciduous Forest	Deciduous Forest	Forest Area
So	32421	saulaie humide sur sol tourbeux ou acide	Weidenbaeume auf einem feuchten, torfigen oder sauren Boden	Deciduous Forest	Deciduous Forest	Forest Area
Sf	32422	saulnaie humide mesotrophe ou eutrophe	Weidenbaeume auf einem feuchten, mittelmaessig oder gut mit Naehrstoffen versorgten Boden	Deciduous Forest	Deciduous Forest	Forest Area
P	313	forets melangees	Mischwald	Mixed Forest	Mixed Forest	Forest Area
Pl	3131	par pied ou par bouquet	truppenweise Mischung (uebernommen aus 1999)	Mixed Forest	Mixed Forest	Forest Area
Pp	3132	par parcelle	Mischung in Parzellen	Mixed Forest	Mixed Forest	Forest Area
H	23	prairies	Wiesen	Grassland	Non-Forest Area	Non-Forest Area
	231	prairies permanentes	Dauerwiesen	Grassland	Non-Forest Area	Non-Forest Area
	2311	prairies semi-naturelles, humides et non-amendees	Halbnatürliche Wiesen	Grassland	Non-Forest Area	Non-Forest Area
Hc	23111	prairie humide peu ou non fertilisee	Feuchtwiese kaum oder nicht geduengt	Grassland	Non-Forest Area	Non-Forest Area
Hj	23112	prairie humide peu ou non fertilisee à joncs	Feuchtwiese kaum oder nicht geduengt mit Binsen	Grassland	Non-Forest Area	Non-Forest Area
Hf	23113	prairie humide a reine des pres	Feuchtwiese mit einem krautigen Rosaceaengewaechs	Grassland	Non-Forest Area	Non-Forest Area
Hm	23114	prairie humide non fertilisee a molinie	ungeduengte Feuchtwiese mit bestimmtem Suessgrasgewaechs	Grassland	Non-Forest Area	Non-Forest Area
Hmo	231141	type oligotrophe	wenig Naehrstoffe	Grassland	Non-Forest Area	Non-Forest Area
Hmm	231142	type mesotrophe	mittelmaessig Naehrstoffe	Grassland	Non-Forest Area	Non-Forest Area
Hme	231143	type eutrophe	viel Naehrstoffe	Grassland	Non-Forest Area	Non-Forest Area
	2312	prairies mesophiles ameliorees	mesophile Weidewiese	Grassland	Non-Forest Area	Non-Forest Area
Hu	23121	prairie mesophile de fauche	mesophile Mahdwiese	Grassland	Non-Forest Area	Non-Forest Area
Hua	23122	prairie mesophile de fauche atypique	untypische mesophile Mahdwiese	Grassland	Non-Forest Area	Non-Forest Area
Hp	23123	pature a ray grass et trefle blanc	Futterpflanzen in breiten Streifen und Klee	Grassland	Non-Forest Area	Non-Forest Area
Hx	23124	prairie a flore tres pauvre	Wiesen mit geringer Biodiversitaet	Grassland	Non-Forest Area	Non-Forest Area
Hr	23125	prairie mesophile abandonnee a flore ruderale	aufgegebene mesophile Wiese mit Ruderalvegetation	Grassland	Non-Forest Area	Non-Forest Area
	32	milieux a vegetation arbustive et/ou herbacee	Gehölze und Buschwerk	Grassland	Non-Forest Area	Non-Forest Area
H	321	pelouses et paturages naturels	Naturnahe Weideflächen	Grassland	Non-Forest Area	Non-Forest Area
Ha	3211	pelouses silicicole a agrostis	Silikatrasen mit irgendeiner Viehfutterpflanze	Grassland	Non-Forest Area	Non-Forest Area
Hn	3212	pelouse silicicole a nard	Silikatraseen mit irgendeiner aromatischen Krautpflanze	Grassland	Non-Forest Area	Non-Forest Area
Hk	3213	pelouse calcaire	Kalkrasen	Grassland	Non-Forest Area	Non-Forest Area
Hkm	32131	sur marne	auf Mergel	Grassland	Non-Forest Area	Non-Forest Area
Hkx	32132	sur sol pierreux	auf steinreichem Boden	Grassland	Non-Forest Area	Non-Forest Area
Hks	32133	sur sol sableux	auf sandreichem Boden	Grassland	Non-Forest Area	Non-Forest Area
Hg	3214	pelouse pionniere des carrieres	Pionierrasen in Steinbruechen	Grassland	Non-Forest Area	Non-Forest Area
Hz	3215	pelouse sur sol intoxique	Rasen auf giftigem (vielleicht schwermetallbelasteten) Gelaende	Grassland	Non-Forest Area	Non-Forest Area
C	322	landes et broussailes	Heide und Buschwerk	Grassland	Non-Forest Area	Non-Forest Area
Cg	3221	lande seche a callune	trockene Heide mit irgendeinem speziellen Heidekrautgewaechs	Grassland	Non-Forest Area	Non-Forest Area
Cj	3222	lande a callune genevrier	Heidekrautgewaechse mit Strauch mit widerstaendigen, stacheligen Blaettern, der Beeren ausbildet	Grassland	Non-Forest Area	Non-Forest Area
Cd	3223	lande a callune degradee	degradierte Heide mit speziellem Heidekrautgewaechs	Grassland	Non-Forest Area	Non-Forest Area
Cdm	32231	a dominance de molinie	mit Dominanz irgendeines Suessgrasgewaechses	Grassland	Non-Forest Area	Non-Forest Area
Cdc	32232	a dominance de canche flexueuse	mit Dominanz einer flexible biegsamen Futterpflanze	Grassland	Non-Forest Area	Non-Forest Area
Cdf	32233	a dominance de fougere aigle	mit Dominanz eines bestimmten Farns	Grassland	Non-Forest Area	Non-Forest Area
Cv	3224	lande seche a myrtille	trockene Heide mit Heidelbeere	Grassland	Non-Forest Area	Non-Forest Area
Ct	3225	lande tourbeuse a myrtille	Torfheide mit Heidelbeere	Grassland	Non-Forest Area	Non-Forest Area
Cs	3226	lande a genets	Heide mit Ginster	Grassland	Non-Forest Area	Non-Forest Area

OBS89 Nomenclature (Part 2/3)						
Acronym	Code	Original in French	translated into German	LULUCF_v7	Forest Types_v7	Forest Areas v7
B	21	terres arables	Ackerland	Cropland annual	Non-Forest Area	Non-Forest Area
	211	terres arables hors perimetre d'irrigation	Ackerland, nicht bewässert	Cropland annual	Non-Forest Area	Non-Forest Area
Ba	2111	culture annuelle	jaehrliche Kulturen	Cropland annual	Non-Forest Area	Non-Forest Area
Bp	2112	pepiniere	Baumschule	Cropland permanent	Non-Forest Area	Non-Forest Area
B	22	cultures permanentes	Dauerkulturen	Cropland permanent	Non-Forest Area	Non-Forest Area
Bv	221	vignobles	Weinberge	Cropland permanent	Non-Forest Area	Non-Forest Area
Bvn	2211	vignobles en pentes	Weinberge in Steillagen	Cropland permanent	Non-Forest Area	Non-Forest Area
Bvt	2212	vignobels en terrasses	Weinberge in Terrassen	Cropland permanent	Non-Forest Area	Non-Forest Area
Bve	2213	vignobles en plaine	Weinberge in ebenen Gebieten	Cropland permanent	Non-Forest Area	Non-Forest Area
Be	222	verges et petits fruits	Streuobst und kleine/niedrigwachsende Fruechte	Cropland permanent	Non-Forest Area	Non-Forest Area
Beh	2221	verges, hautes tiges	Streuobst mit hohen Staemmen	Cropland permanent	Non-Forest Area	Non-Forest Area
Beb	2222	verges, basses tiges	Streuobst mit niedrigen Staemmen	Cropland permanent	Non-Forest Area	Non-Forest Area
U	11	zones urbanisees	Städtisches Gebiet	Settlements	Non-Forest Area	Non-Forest Area
	111	tissu urbain continu	Zusammenhängendes Stadtgebiet	Settlements	Non-Forest Area	Non-Forest Area
Uh	1111	zone urbaine dense	dicht besiedeltes Gebiet	Settlements	Non-Forest Area	Non-Forest Area
Uhh	11111	batiments hauts	mit hohen Gebaeuden	Settlements	Non-Forest Area	Non-Forest Area
Uhb	11112	batiments bas	mit niedrigen Gebaeuden	Settlements	Non-Forest Area	Non-Forest Area
	112	tissu urbain discontinu	Unzusammenhängendes Stadtgebiet	Settlements	Non-Forest Area	Non-Forest Area
Uf	1121	zone semi-urbaine	semiurbaner Raum	Settlements	Non-Forest Area	Non-Forest Area
Ufv	11211	avec vegetation importante	mit bedeutenden Vegetationsanteilen	Settlements	Non-Forest Area	Non-Forest Area
Ufs	11212	sans vegetation importante	ohne bedeutende Vegetationsanteile	Settlements	Non-Forest Area	Non-Forest Area
Ul	1122	extention de l'habitat le long des routes	Siedlungen entlang von Strassen	Settlements	Non-Forest Area	Non-Forest Area
Ue	1123	espace urbain ouvert sans verdure importante	unbebauter staedtischer Raum ohne bedeutende Vegetation	Settlements	Non-Forest Area	Non-Forest Area
Uea	11231	places	Plaetze	Settlements	Non-Forest Area	Non-Forest Area
Uep	11232	parkings	Parkplaetze	Settlements	Non-Forest Area	Non-Forest Area
Uef	11233	friche urbaine	Siedlungsbrache	Settlements	Non-Forest Area	Non-Forest Area
Ur	1124	zone d'habitat rural	laendlicher Siedlungsraum	Settlements	Non-Forest Area	Non-Forest Area
I/T	12	zones industrielles, commerciales et reseaux de communication	Industrie- und Handelsflächen sowie Transportgelände	Settlements	Non-Forest Area	Non-Forest Area
	121	zones industrielles, commerciales et socio-culturelles	Flächen genutzt von Industrie, Handel und Kultur	Settlements	Non-Forest Area	Non-Forest Area
	1211	industrie et commerce	Industrie- und Handelsflächen	Settlements	Non-Forest Area	Non-Forest Area
Il	12111	industrie lourde	Schwerindustrie	Settlements	Non-Forest Area	Non-Forest Area
Iz	12112	zoning industriel (+ domaine militaire)	Industriegebiet (+ militaerische Nutzung)	Settlements	Non-Forest Area	Non-Forest Area
Im	12113	zone d'activites multiples	Zone zahlreicher Nutzungen	Settlements	Non-Forest Area	Non-Forest Area
Is	12114	infrastructure agricole, horticole	Gartenbau- und Landwirtschaftsinfrastruktur	Settlements	Non-Forest Area	Non-Forest Area
	1212	installations socio-culturelles	Flächen für Freizeit- und Kulturnutzung	Settlements	Non-Forest Area	Non-Forest Area
Iu	12121	campus universitaire/ecole	Universitaetscampus und Schulhof	Settlements	Non-Forest Area	Non-Forest Area
If	12122	expositions et foires	Ausstellungen und Messen	Settlements	Non-Forest Area	Non-Forest Area
Ih	12123	hopitaux	Krankenhaeuser	Settlements	Non-Forest Area	Non-Forest Area
Ic	12124	centre culturel et/ou sportif	Zentrum fuer Kultur und Sport	Settlements	Non-Forest Area	Non-Forest Area
	1213	installations specialisees	Sonderflächen	Settlements	Non-Forest Area	Non-Forest Area
It	12131	distribution haute tension	Stromversorgung	Settlements	Non-Forest Area	Non-Forest Area
Ik	12132	installation d'assainissement des eaux usees	Klaeranlage	Settlements	Non-Forest Area	Non-Forest Area
Ir	12133	stockage d'hydrocarbures ou gaz	Gas- oder Kohlenwasserstofftanks	Settlements	Non-Forest Area	Non-Forest Area
	122	reseau routier, ferroviaire et espaces associes	Schienewegenetz und zugehörige Flächen	Settlements	Non-Forest Area	Non-Forest Area
	1221	routes	Strassennetz	Settlements	Non-Forest Area	Non-Forest Area
Ta	12211	autoroutes	Autobahnen	Settlements	Non-Forest Area	Non-Forest Area
Tn	12212	route nationale	Bundesstrasse	Settlements	Non-Forest Area	Non-Forest Area
Tr	12213	chemin repris	Weg zur Entnahme	Settlements	Non-Forest Area	Non-Forest Area
Tc	12214	route communale	Landstrasse	Settlements	Non-Forest Area	Non-Forest Area
Te	12215	chemin d'exploitation	Betriebsstrassen ?	Settlements	Non-Forest Area	Non-Forest Area
Ts	12216	aires et surfaces carrossables	befahrbare Oberflaechen und Plaetze	Settlements	Non-Forest Area	Non-Forest Area
	1222	chemins de fer	schienewegenetz	Settlements	Non-Forest Area	Non-Forest Area
Tg	12221	gare importante	wichtiger Bahnhof	Settlements	Non-Forest Area	Non-Forest Area
Tt	12222	tirage	Zug	Settlements	Non-Forest Area	Non-Forest Area
Tv	12223	voies ferrees	Schienennetz	Settlements	Non-Forest Area	Non-Forest Area
Ip	123	zones portuaires	Hafengebiete	Settlements	Non-Forest Area	Non-Forest Area
Ipi	1231	installation portuaire industrielle	Industriehafen	Settlements	Non-Forest Area	Non-Forest Area
Ipp	1232	zone portuaire de plaisance	Yachthaften	Settlements	Non-Forest Area	Non-Forest Area
Ia	124	aeroports	Flughafen	Settlements	Non-Forest Area	Non-Forest Area
Iah	1241	terminal, hangar	Terminals, Hangar	Settlements	Non-Forest Area	Non-Forest Area
Iaa	1242	piste et taxiways	Landebahnen	Settlements	Non-Forest Area	Non-Forest Area
K	13	mines, decharges et chantiers	Minen, Schutthalden und Baustellen	Settlements	Non-Forest Area	Non-Forest Area
	131	extraction de materiaux (en activite)	Abbauflächen	Settlements	Non-Forest Area	Non-Forest Area
Ks	1311	carriere (sable, pierres …)	Steinbruch	Settlements	Non-Forest Area	Non-Forest Area
Kg	1312	graviere	Kiesgrube	Settlements	Non-Forest Area	Non-Forest Area
Km	1313	mines a ciel ouvert (minerais)	Tagebau	Settlements	Non-Forest Area	Non-Forest Area
	132	decharges et friches	Brachflächen	Settlements	Non-Forest Area	Non-Forest Area
Ko	1321	depotoir	Muelldeponie	Settlements	Non-Forest Area	Non-Forest Area
Ki	1322	crassier et friche industrielle	Halde und industrielle Brache	Settlements	Non-Forest Area	Non-Forest Area
Ky	1323	friche hors zone urbaine et industrielle	Brachen ausserhalb besiedelter und industrieller Gebiete	Settlements	Non-Forest Area	Non-Forest Area
	133	chantiers	Baustellen	Settlements	Non-Forest Area	Non-Forest Area
Kc	1331	chantier en cours	aktuelle Baustellen	Settlements	Non-Forest Area	Non-Forest Area
Ku	1332	surface ruderale ou remblais	Aufschuettungen	Settlements	Non-Forest Area	Non-Forest Area
N	14	espcaes verts artificialises, non agricoles	Grünflachen, nicht landwirtschaftlich genutzt	Settlements	Non-Forest Area	Non-Forest Area
	141	espaces verts urbains	städtische Grünflächen	Settlements	Non-Forest Area	Non-Forest Area
Nc	1411	cimetiere	Friedhof	Settlements	Non-Forest Area	Non-Forest Area
Nv	1412	zone vertes, parcs	Gruenanlagen, Parks	Settlements	Non-Forest Area	Non-Forest Area
Nb	1413	route bordee d'espace vert important	Strasse mit bedeutenden Gruenstreifen	Settlements	Non-Forest Area	Non-Forest Area
Np	1414	parking avec verdure important	Parkplatz mit bedeutender Vegetation	Settlements	Non-Forest Area	Non-Forest Area
	142	equipements sportifs et de loisir	Sport- und Freizeitanlagen	Settlements	Non-Forest Area	Non-Forest Area
Nj	1421	plaine de sport et/ou de jeux	Sport- oder Spielplatz	Settlements	Non-Forest Area	Non-Forest Area
Nr	1422	zone recreative	Erholungsgebiet	Settlements	Non-Forest Area	Non-Forest Area
Ns	1423	amenagement particulier	besondere Einrichtung	Settlements	Non-Forest Area	Non-Forest Area
Ng	1424	cite jardiniere	Kleingartenanlagen	Settlements	Non-Forest Area	Non-Forest Area

OBS89 Nomenclature (Part 3/3)						
Acronym	Code	Original in French	translated into German	LULUCF_v7	Forest Types_v7	Forest Areas v7
M	41	zones humides interieures	Feuchtflächen im Binnenland	Wetland	Non-Forest Area	Non-Forest Area
	411	marais interieurs	Sumpfgebiete	Wetland	Non-Forest Area	Non-Forest Area
Mr	4111	roseliere	Schilf	Wetland	Non-Forest Area	Non-Forest Area
Mrp	41111	a baldingere	mit Rohrglanzgras (aehnlich Schilfrohr)	Wetland	Non-Forest Area	Non-Forest Area
Mrg	41112	a glycerie	wasserliebendes Suessgras mit langen Blaettern	Wetland	Non-Forest Area	Non-Forest Area
Mrs	41113	a jonc des chaisiers	wasserliebendes Kraut mit langem Stengel	Wetland	Non-Forest Area	Non-Forest Area
Mrt	41114	a massette	mit schmalblaettrigem Rohrkolben	Wetland	Non-Forest Area	Non-Forest Area
Mrm	41115	melangee	gemischt	Wetland	Non-Forest Area	Non-Forest Area
Mrr	41116	a roseaux	Schilf	Wetland	Non-Forest Area	Non-Forest Area
Mc	4112	magnocaricaie	Feuchtgebietsvegetation	Wetland	Non-Forest Area	Non-Forest Area
Ms	4113	bas-marais acide	saures Niedermoor	Wetland	Non-Forest Area	Non-Forest Area
Ma	4114	bas-marais alcalin	basisches Niedermoor	Wetland	Non-Forest Area	Non-Forest Area
Mb	4115	bas-marais alcalin ruderalise	basisches Niedermoor (ruderal)	Wetland	Non-Forest Area	Non-Forest Area
	33	espaces ouverts sans ou avec peu de vegetation	Offene Flächen mit wenig oder keiner Vegetation	Other Land	Non-Forest Area	Non-Forest Area
	332	roches nues	Offener Fels	Other Land	Non-Forest Area	Non-Forest Area
G	3321	carriere abondonnee	aufgegebener Steinbruch	Other Land	Non-Forest Area	Non-Forest Area
A	51	eaux continentales	Wasserflächen im Binnenland	Water	Non-Forest Area	Non-Forest Area
	511	cours et voies d'eaux	Wasserläufe und -strassen	Water	Non-Forest Area	Non-Forest Area
An	5111	cours d'eau natuels	natuerliche Wasserlaeufe	Water	Non-Forest Area	Non-Forest Area
Ac	5112	voies d'eau artificielles	kuenstliche Wasserlaeufe	Water	Non-Forest Area	Non-Forest Area
	512	plans d'eau	Wasserflächen (Seen, Teiche etc.)	Water	Non-Forest Area	Non-Forest Area
Al	5121	plan d'eau naturel	natuerliche Wasserflaeche	Water	Non-Forest Area	Non-Forest Area
Alh	51211	plus ou mojns sale	mehr oder weniger salzhaltig	Water	Non-Forest Area	Non-Forest Area
Alo	51212	oligotrophe	wenig Naehrstoffe	Water	Non-Forest Area	Non-Forest Area
Alm	51213	mesotrophe	mittelmaessig Naehrstoffe	Water	Non-Forest Area	Non-Forest Area
Ale	51214	eutrophe	viel Naehrstoffe	Water	Non-Forest Area	Non-Forest Area
Aa	5122	plan d'eau artificiel	kuenstliche Wasserflaeche	Water	Non-Forest Area	Non-Forest Area
Aah	51221	plus ou mojns sale	mehr oder weniger salzhaltig	Water	Non-Forest Area	Non-Forest Area
Aao	51222	oligotrophe	wenig Naehrstoffe	Water	Non-Forest Area	Non-Forest Area
Aam	51223	mesotrophe	mittelmaessig Naehrstoffe	Water	Non-Forest Area	Non-Forest Area
Aae	51224	eutrophe	viel Naehrstoffe	Water	Non-Forest Area	Non-Forest Area
Ab	5123	bras mort	Altarm	Water	Non-Forest Area	Non-Forest Area
?	5124	petit plan d'eau, mardelle	Teich	Water	Non-Forest Area	Non-Forest Area
Ar	5125	bassin, reservoir, etc. …	Becken, Reservoir	Water	Non-Forest Area	Non-Forest Area
Aro	51251	oligotrophe	wenig Naehrstoffe	Water	Non-Forest Area	Non-Forest Area
Arm	51252	mesotrophe	mittelmaessig Naehrstoffe	Water	Non-Forest Area	Non-Forest Area
Are	51253	eutrophe	viel Naehrstoffe	Water	Non-Forest Area	Non-Forest Area
Arz	51254	sans valeur biologique	ohne biologischen Wert	Water	Non-Forest Area	Non-Forest Area

Table 6-5 – OBS99/07 - LULUCF matching table

OBS99/07 Nomenclature							
German Acronym	French Acronym	Code	Original in French	translated into German	LULUCF_v7	Forest Types_v7	Forest Areas v7
WLE	FFC	3.1.1.1	Laubwald, Eiche	Futaie feuillue α dominance de chene	Deciduous Forest	Deciduous Forest	Forest
WLB	FFH	3.1.1.2	Laubwald, Buche	Futaie feuillue α dominance de hetre	Deciduous Forest	Deciduous Forest	Forest
WLS	FFD	3.1.1.3	Laubwald, sonstige Laubbaumarten	Futaie de feuillus divers	Deciduous Forest	Deciduous Forest	Forest
WLM	FFM	3.1.1.4	Laubwald, gemischt, Eiche, Buche	Futaie feuillue melangee de chenes et de hetres	Deciduous Forest	Deciduous Forest	Forest
WLN	FTC	3.1.1.5	Eichen-Niederwald	Taillis de chene	Deciduous Forest	Deciduous Forest	Forest
WL0	FFP	3.1.1.6.1	Laubwald, Pappel-Monokulturen	Peupleraie et autres monocultures feuillues	Deciduous Forest	Deciduous Forest	Forest
SBT	BPS	3.2.4.1	Buschwerk, Vorwaelder trockener Standorte	Buissons, prebois sur sols secs	Deciduous Forest	Deciduous Forest	Forest
SBM	BPF	3.2.4.2	Buschwerk, Vorwaelder mittlerer Standorte	Buissons, prebois sur sols frais	Deciduous Forest	Deciduous Forest	Forest
SBF	BPH	3.2.4.3	Buschwerk, Vorwaelder feuchter Standorte	Buissons, prebois sur sols humides	Deciduous Forest	Deciduous Forest	Forest
SBG	BPE	3.2.4.4	Blockschutt- und Geroellwaelder	Forets, prebois sur eboulis	Deciduous Forest	Deciduous Forest	Forest
SBP	BPA	3.2.4.5	Gehoelzplanzungen	Plantations cubustives	Deciduous Forest	Deciduous Forest	Forest
WNF	FRE	3.1.2.1	Nadelwald, Fichte/Douglasie/Tanne	Foret resineuse (epiceas, douglas, sapins)	Coniferous Forest	Coniferous, Spruce/Douglas Fir/Fir	Forest
WNK	FRP	3.1.2.2	Nadelwald, Kiefer/Laerche	Foret resineuse (pins, melezes et autres resineux)	Coniferous Forest	Coniferous Pine/Larch	Forest
WNM	FRM	3.1.2.3	Nadelwald, gemischt	Foret resineuse melangee	Coniferous Forest	Coniferous mixed	Forest
WMT	FMP	3.1.3.1	Mischwald (Laub/Nadel), truppweise Mischung	Foret melangee (feuillus/resineux) par pied, par bouquet	Mixed forest	Mixed forest	Forest
WMF	FMM	3.1.3.2	Mischwald (Laub/Nadel), fliessende Mischung	Foret melangee (feuillus/resineux), melange intime	Mixed forest	Mixed forest	Forest
WAU	FCD	3.1.3.3	Aufforstungen, Landungen, Dickungen (Baumart nicht erkennbar)	Culture forestiere d'essences non definies	Mixed forest	Mixed forest	Forest
WSF	FSD	3.1.3.4	Sonstige Forest Landflaechen (Schlagflur, Windbruch)	Autres surfaces forestieres (coupes rases, chablis)	Mixed forest	Mixed forest	Forest
LAA	RAA	2.1.1.1	Acker	Terres agricoles, cultures annuelles	Cropland annual	Non-Forest	Non-Forest
LBG	RAH	2.1.1.2	Baumschule, Gartenbau	Pepinieres, horticulture, arbres de Noðl	Cropland permanent	Non-Forest	Non-Forest
LWT	RVT	2.2.1.1	Weinbau, Terrasse	Vignoble en terrasse	Cropland permanent	Non-Forest	Non-Forest
LWS	RVA	2.2.1.2	Weinbau, sonstige	Autres vignoble	Cropland permanent	Non-Forest	Non-Forest
LSH	RHT	2.2.2.1	Streuobst, Hochstamm	Verger α hautes tiges	Cropland permanent	Non-Forest	Non-Forest
LSN	RBT	2.2.2.2	Obst, Niederstamm	Verger α basses tiges	Cropland permanent	Non-Forest	Non-Forest
LFG	RPR	2.3.1.1	Feuchtgruenland	Prairie humide	Grassland	Non-Forest	Non-Forest
LMG	RPM	2.3.1.2	Mesophiles Gruenland	Prairie mesophile	Grassland	Non-Forest	Non-Forest
KSI	PSI	3.2.1.1	Silicattrockenrasen	Pelouse silicicole	Grassland	Non-Forest	Non-Forest
KKA	PCA	3.2.1.2	Kalkmagerrasen	Pelouse calcaire	Grassland	Non-Forest	Non-Forest
KFE	PSR	3.2.1.3	Fels- und Schotterrasen, Pionierfluren	Pelouses pionnieres (sur substrat rocheux ou graveleux)	Grassland	Non-Forest	Non-Forest
KHE	PLR	3.2.2	Heiden, Rohbodenstandorte	Landes, sols nus	Grassland	Non-Forest	Non-Forest
KRM	PFR	3.2.3.1	Ruderalstandorte, Staudenfluren mittlerer bis trock	Surfaces ruderalisees et friches sur sols secs α frais	Grassland	Non-Forest	Non-Forest
KRF	PFH	3.2.3.2	Ruderalstandorte, Staudenfluren feuchter Standorte	Surfaces ruderalisees et friches sur sols humides	Grassland	Non-Forest	Non-Forest
BSC	UAD	1.1.1	Siedlungsgebiet, Verdichtungsgrad >80%, City	Tissu urbain dense (degree de l'impermêabilisation des sols >80%)	Settlements	Non-Forest	Non-Forest
BSM	UAA	1.1.2.1.1	Siedlungsgebiet mit Verdichtunggrad von 50-80%	Zone semi-urbaine, degree de l'impermêabilisation des sols 50-80%	Settlements	Non-Forest	Non-Forest
BSO	UAS	1.1.2.1.2	Siedlungsgebiet Verdichtungsgrad 30-50%	Zone semi-urbaine, degree de l'impermêabilisation des sols 30-50%	Settlements	Non-Forest	Non-Forest
BSB	UAL	1.1.2.2	Siedlungsbaender entlang von Strassen	Urbanisation longiligne, Bandes urbanisees le long des routes	Settlements	Non-Forest	Non-Forest
BSP	UAP	1.1.2.3.1	Oeffentliche Plaetze	Place	Settlements	Non-Forest	Non-Forest
BSR	UAF	1.1.2.3.2	Siedlungsbrachen ohne/geringe Vegetation	Friche urbaine, Espace urbain ouvert sans verdure importante	Settlements	Non-Forest	Non-Forest
BSE	UAH	1.1.2.4	Einzelhaeuser, Hoefe etc. ausserhalb Bebauung	Habitat dissemine en zone rurale, hameau	Settlements	Non-Forest	Non-Forest
BII	UIL	1.2.1.1.1	Industrie	Industrie lourde	Settlements	Non-Forest	Non-Forest
BIG	UIA	1.2.1.1.2	Gewerbe, Militaer, Dienstleistung	Zone d'activites economiques, terrain militaire	Settlements	Non-Forest	Non-Forest
BIO	UPS	1.2.1.2	Oeffentliche Bebauung	BΓtiments et installations α destination socio-culturelle	Settlements	Non-Forest	Non-Forest
BIS	UPE	1.2.1.3.1	Sondergebiete, Stromversorgung	Installations de distribution electrique	Settlements	Non-Forest	Non-Forest
BIW	UPU	1.2.1.3.2	Sondergebiete, Wasserversorgung	Installation de traitement des eaux usees	Settlements	Non-Forest	Non-Forest
BIA	UPH	1.2.1.3.3	Sondergebiete, Gasversorgung	Installations de stockage d'hydrocarbures et de gaz	Settlements	Non-Forest	Non-Forest
BIL	UAC	1.2.1.4	gewerbliche Landwirtschaft (Stallanlagen, Gewaechshaeuser)	Constructions agricoles et horticoles, etables, serres	Settlements	Non-Forest	Non-Forest
BVS	UTR	1.2.2.1.1	bedeutende Strassen (>20m)	Routes importantes (>20m), voies rapides	Settlements	Non-Forest	Non-Forest
BVP	UTS	1.2.2.1.2	Parkplatz	Zones de stationnement	Settlements	Non-Forest	Non-Forest
BVB	UTF	1.2.2.2	Bahnanlage	Infrastructure ferroviaire, gare	Settlements	Non-Forest	Non-Forest
BVH	UTP	1.2.3	Hafengebiete	Zone portuaire	Settlements	Non-Forest	Non-Forest
BVT	UTA	1.2.4.1	Flughafen, Gebaeude, Terminal	Aeroport; terminal, hangar	Settlements	Non-Forest	Non-Forest
BVL	UTT	1.2.4.2	Flughafen, Landebahn	Aeroport; piste et taxiways	Settlements	Non-Forest	Non-Forest
BAF	UEM	1.3.1	Abbauflaeche, Tagebau	Zone d'extraction de materiaux	Settlements	Non-Forest	Non-Forest
BAA	UER	1.3.2.1	Aufschuettung, Deponie	Remblais et decharges	Settlements	Non-Forest	Non-Forest
BAH	UEC	1.3.2.2	Halden	Crassier	Settlements	Non-Forest	Non-Forest
BAB	UEF	1.3.2.3	Brachen industrieller Gebiete	Friche industrielle	Settlements	Non-Forest	Non-Forest
BAU	UEH	1.3.2.4	Baustellen	Chantier	Settlements	Non-Forest	Non-Forest
BGF	UVC	1.4.1.1	Friedhoefe	Cimetiere	Settlements	Non-Forest	Non-Forest
BGG	UVV	1.4.1.2	Gruenanlagen, Parks	Zones de verdure, parcs	Settlements	Non-Forest	Non-Forest
BGS	UVS	1.4.2.1	Sport-, Spiel-, Camping-, Golfplaetze	Terrain de sport, espace recreatif, camping, golf etc.	Settlements	Non-Forest	Non-Forest
BGK	UVJ	1.4.2.2	Kleingartenanlagen	Cite jardiniere	Settlements	Non-Forest	Non-Forest
FRO	ROS	4.1.1.1	Roehrichte	Roseliere	Wetland	Non-Forest	Non-Forest
FGS	MAG	4.1.1.2	Grossseggenrieder	Magnocariτaie	Wetland	Non-Forest	Non-Forest
FKS	MBA	4.1.1.3	Kleinseggenrieder	Bas marais	Wetland	Non-Forest	Non-Forest
OFF	RNU	3.3.2	Offene Felsflaechen	Roche nue	Other Land	Non-Forest	Non-Forest
OFK	RNU	3.3.2	Offene Felsflaechen < 1500m2	Roche nue < 1500m2	Other Land	Non-Forest	Non-Forest
OBS	REN	3.3.2.1	Offene Blockschutt- und Schotterflaechen	Eboulis et graviers non colonises	Other Land	Non-Forest	Non-Forest
GFN	ECN	5.1.1.1.1	Fliessgewaesser natuerlicher Entstehung, naturnah	Cours d'eau naturel	Water	Non-Forest	Non-Forest
GFF	ECA	5.1.1.1.2	Fliessgewaesser natuerlicher Entstehung, naturfern	Cours d'eau artificialise	Water	Non-Forest	Non-Forest
GFK	EEA	5.1.1.2	Fliessgewaesser kuenstlicher Entstehung	Cours d'eau artificiels	Water	Non-Forest	Non-Forest
GSN	EPN	5.1.2.1	Stillgewaesser natuerlicher Entstehung	Plans d'eau anthropogene proche de l'etat naturel	Water	Non-Forest	Non-Forest
GSK	EPA	5.1.2.2	Stillgewaesser kuenstlicher Entstehung	Plan d'eau artificiel	Water	Non-Forest	Non-Forest
GAA	EBM	5.1.2.3	Altarme, Altwasser	Bras mort	Water	Non-Forest	Non-Forest
GMD	EMA	5.1.2.4	"Mardelle"	Mardelle	Water	Non-Forest	Non-Forest
GBB	BRE	5.1.2.5.1	Becken, Reservoir von biol. Interesse	Bassin, reservoir ayant un interet ecologique	Water	Non-Forest	Non-Forest
GBO	BRS	5.1.2.5.2	Becken, Reservoir ohne biol. Wert	Bassin, reservoir α ciel ouvert sans interet ecologique	Water	Non-Forest	Non-Forest

6.1.3.3 Methodology used to develop the land transition matrix

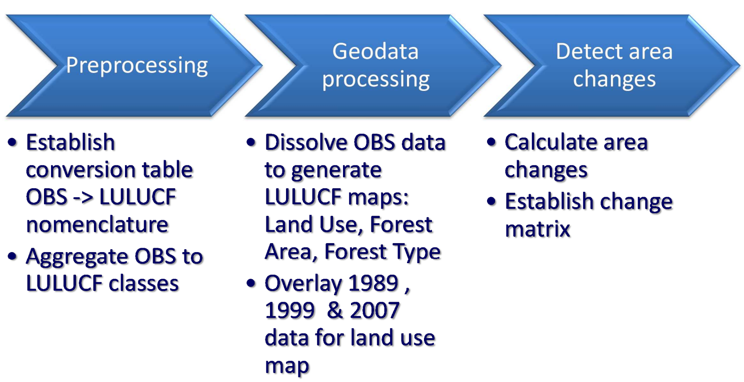
The generation of the LULUCF maps is based on the OBS and RE data. Data processing of OBS89, OBS99 and OBS07 follows the same processing scheme.

The original OBS categories for the years 1989, 1999 and 2007 were assigned to the relevant classes of the LULUCF nomenclatures. The correspondence of OBS89 respectively OBS99/07 classification to the LULUCF nomenclature has been established in close collaboration with the relevant administrations and experts. The conversion tables from OBS89-99-07 to LULUCF are presented in the above section. For RE data, the areas were directly assigned to the corresponding land use classes of the LULUCF nomenclature

After aggregation of the class assignments according to the LULUCF nomenclature (for OBS data), the next step in geo data processing (using Geographic Information System software "ArcGIS") is to dissolve the polygons to the respective classes, *i.e.* all neighbouring polygons belonging to the same LULUCF class were aggregated to one single polygon. This process results in land use maps, *i.e.* LU89, LU99, LU07 and LU12.

In order to preserve the detail in the data for the generation of the area statistics, no generalisation was performed before the change detection. Change detection of Land Use / Forest types between the selected reference years 1989, 1999 and 2007 has been carried out by overlay (intersect) of the Land Use maps LU89, LU99 and the LU07 data sets. Figure 1-2 shows the processing steps.

Figure 6-2 – Processing chain for the creation of LULUCF maps



For the change detection between the reference years 2007 and 2012, the overlay (intersect) of land use maps LU07 and LU12 has been carried out using the following processing steps. (Figure 1-3)

Figure 6-3– Processing chain for the creation of LU12 and change detection between LU07 and LU12

The resulting maps of the intersection show the differences in land use and the changes from which land use class to which other one. The total area as computed from the GIS data sets differs slightly from the official area of the Luxembourg territory. This is simply due to resolution /scale and data processing inaccuracies in the data sets. Therefore, the areas derived from the geodata have been put in relation to the official area of Luxembourg (258 600 ha). It means that all areas resulting from the geodata processing are proportional to the official territory of Luxembourg that is 2 586 km^2. From this data the change statistics are derived and illustrated in the change matrix.

6.1.3.4 Surface statistics according to LULUCF categories

Table 6-6 – Land use change matrix (1989-1999) surfaces (ha) according to LULUCF categories (raw data)

	LULUCF 1999 (raw data ha)	1989											
		settlements	cropland	permanent crops	grassland	deciduous forest	coniferous forest	mixed forest	forest without trees	other land	wetland	water	Totals 1999
1999	settlements	17 837.0	1 107.7	480.6	2 747.8	619.1	238.3	27.7		55.0	14.7	67.4	**23 195**
	cropland	289.3	36 254.4	172.8	9 315.0	358.5	229.3	4.7		5.7	9.1	14.1	**46 653**
	permanent crops	363.1	219.0	3 170.1	758.6	120.6	29.2	2.4		2.3	0.4	1.9	**4 668**
	grassland	2 267.8	17 692.2	1 568.7	62 565.4	1 697.3	956.2	36.8		188.3	143.9	140.6	**87 257**
	deciduous forest	1 176.3	580.1	407.6	2 260.6	49 621.4	3 438.1	371.2		571.7	51.9	108.5	**58 587**
	coniferous forest	90.4	218.7	37.0	578.6	2 866.5	18 665.6	129.8		18.8	3.9	12.5	**22 622**
	mixed forest	155.4	198.2	32.2	467.8	7 581.7	5 802.6	165.9		21.1	4.5	6.1	**14 435**
	forest without trees												**0**
	other land	10.7	0.2	0.0	0.9	11.3	3.6	0.5		30.3	0.0	0.8	**58**
	wetland	4.3	6.5	0.7	95.5	12.1	10.9	0.3		0.0	65.0	11.3	**207**
	Water	55.9	11.7	1.1	54.6	44.3	10.7	2.1		0.3	3.2	733.4	**917**
	Totals 1989	**22 250**	**56 289**	**5 871**	**78 845**	**62 933**	**29 384**	**741**		**893**	**297**	**1 097**	**258 600**

Table 1-6 is a change matrix showing the land use changes that have occurred between 1989 and 1999 according to the OBS maps of 1989 and 1999. Grey marked cells are the land uses that have not changed and remained within their category. Highlighted in red are the land uses changes between cropland and grassland. Both OBS maps were partially based on aerial colour infra-red and ortho-photos. Those types of photos do not allow differentiating between permanent changes from grassland to cropland and a temporary grass cover on a crop rotation. In Luxembourg, and especially in the northern part of Luxembourg (Oesling), a crop rotation including temporary grass is largely used by the farmers. An alternative way to estimate the LUC between cropland and grassland was found, using administrative data of the Ministry of Agriculture coming from the administration of the "aid scheme for the maintenance of the landscape and the natural environment and for encouraging an agriculture respecting the environment", an agro-environmental aid scheme administered by the "Service d'Economie Rurale", an administration of the Ministry of Agriculture. As a land use change from permanent grassland to cropland is not allowed within this aid scheme, except in special circumstances and after a special authorization and as this aid scheme is largely taken up by the farmers, it was possible to estimate the annual LUC grassland to cropland (269 ha). Similarly the permanent change from cropland to grassland was also estimated at 269 ha. Thus, the LUC areas grassland to cropland respectively cropland to grassland going beyond 269 ha according to OBS are allocated to the category "cropland remaining cropland". Hence the change matrix was modified as followed with the changed values highlighted in green:

Table 6-7 – Modified Land use change matrix (1989-1999)

	LULUCF 1999 (modified data ha	1989											
		settlements	Cropland	permanent crops	grassland	deciduous forest	coniferous forest	mixed forest	forest without trees	other land	wetland	water	**Totals 1999**
1999	settlements	17 837.0	1 107.7	480.6	2 747.8	619.1	238.3	27.7		55.0	14.7	67.4	**23 195**
	cropland	289.3	57 881.6	172.8	2 690.0	358.5	229.3	4.7		5.7	9.1	14.1	**61 655**
	permanent crops	363.1	219.0	3 170.1	758.6	120.6	29.2	2.4		2.3	0.4	1.9	**4 668**
	grassland	2 267.8	2 690.0	1 568.7	62 565.4	1 697.3	956.2	36.8		188.3	143.9	140.6	**72 255**
	deciduous forest	1 176.3	580.1	407.6	2 260.6	49 621.4	3 438.1	371.2		571.7	51.9	108.5	**58 587**
	coniferous forest	90.4	218.7	37.0	578.6	2 866.5	18 665.6	129.8		18.8	3.9	12.5	**22 622**
	mixed forest	155.4	198.2	32.2	467.8	7 581.7	5 802.6	165.9		21.1	4.5	6.1	**14 435**
	forest without trees												**0**
	other land	10.7	0.2	0.0	0.9	11.3	3.6	0.5		30.3	**0.0**	0.8	**58**
	wetland	4.3	6.5	0.7	95.5	12.1	10.9	0.3		0.0	65.0	11.3	**207**
	Water	55.9	11.7	1.1	54.6	44.3	10.7	2.1		0.3	3.2	733.4	**917**
	Totals 1989	**22 250**	**62 914**	**5 871**	**72 220**	**62 933**	**29 384**	**741**	**0**	**893**	**297**	**1 097**	**258 600**

It is important to highlight two points:

- Changing the values in the change matrix unfortunately leads to certain inconsistencies when comparing the change matrix 1989/1999 with the change matrix 1999/2007. This becomes clear when comparing the total grassland and total cropland areas generated for the year 1999 (see comparison with Table 1-9).
- It is also possible that a cropland under rotation was covered in grass in 1989 and 1999 during satellite or ortho-photo imagery and was subsequently put in the category grassland. There is however no immediate possibility to change the data in the short term. The category grassland can thus be slightly overestimated in comparison to the cropland category.

The change matrix showing the land use changes between 1999 and 2007 was established in a similar way to the change matrix between 1989 and 1999 and is shown here below (Table 1-8):

Table 6-8 – Land use change matrix (1999-2007) surfaces (ha) according to LULUCF categories (raw data)

	LULUCF 2007 (raw data ha)	1999 Settlements	cropland	permanent crops	grassland	deciduous forest	coniferous forest	mixed forest	forest without trees	other land	wetland	water	Totals 2007
2007	settlements	21 726.5	430.7	149.2	1 798.1	378.2	55.5	62.2	0.0	1.2	2.0	16.3	**24 620**
	cropland	108.1	42 923.4	39.8	14 206.3	31.3	17.9	37.2	0.0	0.0	2.1	0.2	**57 366**
	permanent crops	94.4	92.3	4 245.6	414.3	32.5	3.9	22.6	0.0	0.0	0.0	0.2	**4 906**
	grassland	812.7	3 084.8	177.8	69 854.3	216.8	91.1	107.7	0.0	0.5	12.1	20.7	**74 379**
	deciduous forest	289.7	61.5	42.2	475.0	55 320.1	139.5	179.7	0.0	0.9	1.4	9.3	**56 519**
	coniferous forest	48.3	10.4	1.1	64.0	108.4	20 029.3	157.1	0.0	0.2	0.1	0.3	**20 419**
	mixed forest	70.7	36.5	4.2	295.8	2 377.9	1 399.5	13 608.6	0.0	1.9	0.9	1.1	**17 797**
	forest without trees	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1 303.9	0.0	0.0	0.0	**1 304**
	other land	0.5	0.1	0.0	0.5	1.3	0.1	0.0	0.0	53.5	0.0	0.0	**56**
	wetland	0.5	1.7	0.2	21.8	4.6	1.2	0.7	0.0	0.0	186.6	1.1	**218**
	water	30.2	13.6	0.8	75.5	23.1	0.9	2.2	0.0	0.0	1.6	867.6	**1 016**
	Totals 1999	**23 182**	**46 655**	**4 661**	**87 206**	**58 494**	**21 739**	**14 178**	**1 304**	**58**	**207**	**917**	**258 600**

Table 1-9 shows the modified change matrix between the year 1999 and 2007. Here as well land uses changes between cropland and grassland have been set to a fixed value of 269 ha per year and remaining land use change areas have been added to the category cropland remaining cropland.

Table 6-9 – Modified land use change matrix (1999-2007) surfaces (ha)

	LULUCF 1999 (modified data ha)	1999 settlements	cropland	permanent crops	grassland	deciduous forest	coniferous forest	mixed forest	forest without trees	other land	wetland	water	**Totals 2007**
2007	Settlements	21 726.5	430.7	149.2	1 798.1	378.2	55.5	62.2	0.0	1.2	2.0	16.3	**24 619.9**
	Cropland	108.1	55 910.4	39.8	2 152.0	31.3	17.9	37.2	0.0	0.0	2.1	0.2	**58 299.0**
	permanent crops	94.4	92.3	4 245.6	414.3	32.5	3.9	22.6	0.0	0.0	0.0	0.2	**4 905.9**
	Grassland	812.7	2 152.0	177.8	69 854.3	216.8	91.1	107.7	0.0	0.5	12.1	20.7	**73 445.8**
	deciduous forest	289.7	61.5	42.2	475.0	55 320.1	139.5	179.7	0.0	0.9	1.4	9.3	**56 519.1**
	coniferous forest	48.3	10.4	1.1	64.0	108.4	20 029.3	157.1	0.0	0.2	0.1	0.3	**20 419.2**
	mixed forest	70.7	36.5	4.2	295.8	2 377.9	1 399.5	13 608.6	0.0	1.9	0.9	1.1	**17 797.2**
	forest without trees	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1 303.9	0.0	0.0	0.0	**1 303.9**
	other land	0.5	0.1	0.0	0.5	1.3	0.1	0.0	0.0	53.5	0.0	0.0	**56.1**
	Wetland	0.5	1.7	0.2	21.8	4.6	1.2	0.7	0.0	0.0	186.6	1.1	**218.4**
	Water	30.2	13.6	0.8	75.5	23.1	0.9	2.2	0.0	0.0	1.6	867.6	**1 015.5**
	Totals 1999	**23 182**	**58 709**	**4 661**	**75 151**	**58 494**	**21 739**	**14 178**	**1 304**	**58**	**207**	**917**	**258 600**

As already mentioned above, changing the data between cropland and grassland leads to the fact that both change matrixes (Table 1-7 & Table 1-9) will give different results for the total area of grassland as well as cropland.

Table 6-10 – Land use change matrix (2007-2012) surfaces (ha) according to LULUCF categories (raw data)

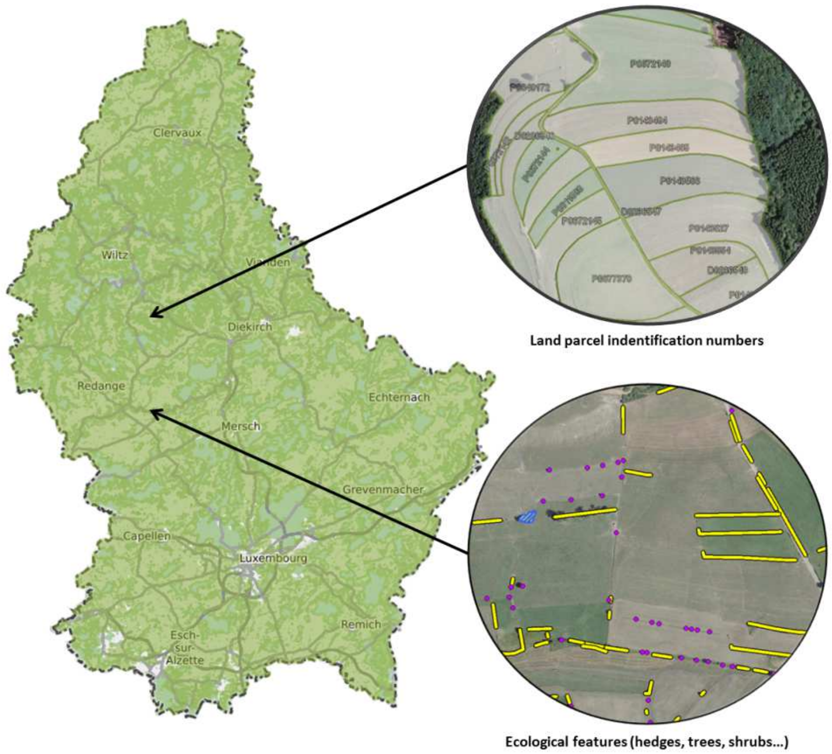
	LULUCF 2007 (raw data ha)	2007											Totals 2012
		settlements	cropland	permanent crops	grassland	deciduous forest	coniferous forest	mixed forest	forest without trees	other land	wetland	water	
2012	settlements	24 593.0	140.1	23.7	450.3	44.4	5.1	19.9	1.3	0.0	0.0	3.5	25 281
	cropland	0.7	57 090.1	0.7	300.9	1.4	14.4	0.6	13.1	0.0	0.0	0.0	57 422
	permanent crops	6.2	0.0	4 867.4	0.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	4 874
	grassland	10.7	102.4	1.6	73 417.8	8.5	75.0	9.9	0.5	0.0	0.0	0.4	73 627
	deciduous forest	0.3	5.3	0.1	88.6	56 353.3	0.1	0.0	22.3	0.0	0.5	0.1	56 471
	coniferous forest	2.6	3.7	0.6	9.9	0.1	19 236.3	0.0	4.6	0.0	0.0	0.0	19 258
	mixed forest	1.7	1.8	8.7	70.5	0.5	0.2	17 720.5	195.1	0.0	0.5	0.0	17 999
	forest without trees	3.2	22.2	3.2	39.7	109.8	1 087.9	46.3	1 066.1	1.3	0.0	0.0	2 380
	other land	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	54.8	0.0	0.0	55
	wetland	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	217.3	0.7	218
	water	1.5	0.5	0.0	0.6	0.6	0.0	0.0	0.9	0.0	0.1	1 010.8	1 015
	Totals 2007	24 6209	57 366	4 906	74 379	56 519	20 419	17 797	1 304	56	218	1 016	258 600

Table 1-10 is the change matrix for the year 2007 to 2012. For the preparation of this project multi-temporal RapidEye images have been acquired in March, April and in August 2012. Multi-temporal imagery analysis means that the interpretation is based on at least 2 images over the area of interest at different points in time, best in accordance with the vegetation period and the harvesting time. This allows a better distinction between cropland (i.e. arable land that is ploughed: bare in spring and after harvest) and grassland (permanent grass vegetation). As a result the land use change between cropland and grassland were so small that there is no need to amend the data for this change matrix.

Using satellite imagery at two different moments of the year is however not necessarily sufficient to distinguish between a cropland that has a grass cover as part of its rotation and grassland. The grass cover during a rotation stays in general for about 2 years on a field and will give the same satellite image during spring as during autumn.

Nevertheless the data will not be used as Luxembourg is operating a detailed LPIS (Land Parcel Identification System since 2009). The LPIS is being used for registration of reference parcels considered eligible for direct payments of CAP subsidies to farmers. Information contained in the LPIS includes parcel area and boundaries, crop description and land owner or herd number. Its role is to identify and quantify the land eligible for payments.

Figure 6-4 – Land Parcel Identification System (LPIS) in Luxembourg



A year on year analysis can be difficult as the data is not stable over time (e.g. changes in boundaries, intermittent recording when parcels are not subject to payment claims, changes in ownership). The data is spatially explicit and offers the opportunity to analyse gross land-use changes between crops (mainly grassland to cropland and vice versa).

The main advantage of using LPIS information (especially for areas with grass cover) is that it allows circumventing the problems between Land Cover vs Land Use data. The data from the OBS represents land cover rather than land use. Hence a cropland with an intermediate grass cover is perceived as grassland whereas the same parcel is clearly labelled as cropland under the LPIS system.

The disadvantage of the LPIS system is that it includes only those areas eligible for CAP payments, which means that +/- 4.000 ha are not included (predominantly perennial cropland but also a lot of grassland along highways and roads for example). Total cropland and grassland areas obtained via a detailed land use/land cover map of Luxembourg in combination with satellite imagery and aerial photography are hence still more relevant.

The following procedures were taken in order to utilise the data:

- The database was reduced to a utilisable **subset:** The database was reduced to those fields that maintained the same identification number between 2009 and 2015 and to those that had a surface >0.1 ha. This lead to a reduction of the sample of +/- 30,000 entries. A further reduction has been undertaken to filter out those entries where no crop was declared in any of the years between 2009 and 2015. This lead to a reduction of a further 4,600 entries. The chosen subset represents 94,397 ha compared to approximately 126,000 ha in the total database.
- Land use change between grassland and cropland were only considered if they occurred only once between 2009 and 2015. Multiple land use changes are generally considered to be crop rotation on cropland.
- The land use changes between cropland and grassland were expressed in %. In order to determine absolute land use changes those % were applied to the sum of grassland and cropland as determined by the OBS maps in 2012 (131,049 ha).

Table 6-11 – Land use changes between grassland and cropland extrapolated from LPIS database

	2009	2010	2011	2012	2013	2013	2015
cropland -> grassland (LPIS)	0.46%	0.34%	0.19%	0.17%	0.09%	0.49%	0.46%
grassland ->cropland (LPIS)	0.33%	0.26%	0.30%	0.24%	0.23%	0.27%	0.33%
cropland -> grassland (ha)	597.6	451.3	245.4	219.4	114.0	597.6	451.3
grassland ->cropland (ha)	430.2	343.7	393.6	318.7	302.6	430.2	343.7

Table 6-12 – Modified land use change matrix (2007-2012) surfaces (ha)

	LULUCF 2007 (raw data ha)	2007 settlements	cropland	permanent crops	grassland	deciduous forest	coniferous forest	mixed forest	forest without trees	other land	wetland	water	Totals 2012
2012	settlements	24 593.0	140.1	23.7	450.3	44.4	5.1	19.9	1.3	0.0	0.0	3.5	25 281
	cropland	0.7	55 360.2	0.7	1 705.5	1.4	14.4	0.6	13.1	0.0	0.0	0.0	57 097
	permanent crops	6.2	0.0	4 867.4	0.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	4 874
	grassland	10.7	1 832.3	1.6	72 013.1	8.5	75.0	9.9	0.5	0.0	0.0	0.4	73 952
	deciduous forest	0.3	5.3	0.1	88.6	56 353.3	0.1	0.0	22.3	0.0	0.5	0.1	56 471
	coniferous forest	2.6	3.7	0.6	9.9	0.1	19 236.3	0.0	4.6	0.0	0.0	0.0	19 258
	mixed forest	1.7	1.8	8.7	70.5	0.5	0.2	17 720.5	195.1	0.0	0.5	0.0	17 999
	forest without trees	3.2	22.2	3.2	39.7	109.8	1 087.9	46.3	1 066.1	1.3	0.0	0.0	2 380
	other land	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	54.8	0.0	0.0	55
	wetland	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	217.3	0.7	218
	water	1.5	0.5	0.0	0.6	0.6	0.0	0.0	0.9	0.0	0.1	1 010.8	1 015
	Totals 2007	24 6209	57 366	4 906	74 379	56 519	20 419	17 797	1 304	56	218	1 016	258 600

Table 6-13 – Land Cover surfaces (ha) according to LULUCF categories

4 - Land Use, Land Use Change & Forestry							
Land cover surfaces (ha)							
Year	A Forestland	B Cropland	C Grassland	D Wetlands	E Settlements	F Other land	Note
1989	*93 059*	*68 785*	*72 220*	*1 393*	*22 250*	*893*	*OBS89*
1990	*93 317*	*68 538*	*72 223*	*1 366*	*22 345*	*810*	*linear interpolation*
1991	*93 576*	*68 292*	*72 227*	*1 339*	*22 439*	*726*	
1992	*93 835*	*68 046*	*72 230*	*1 312*	*22 534*	*643*	
1993	*94 093*	*67 800*	*72 234*	*1 286*	*22 628*	*559*	
1994	*94 352*	*67 554*	*72 237*	*1 259*	*22 723*	*476*	
1995	*94 610*	*67 307*	*72 241*	*1 232*	*22 817*	*392*	
1996	*94 869*	*67 061*	*72 244*	*1 205*	*22 912*	*309*	
1997	*95 128*	*66 815*	*72 248*	*1 178*	*23 006*	*225*	
1998	*95 386*	*66 569*	*72 251*	*1 151*	*23 101*	*142*	
1999	*95 645*	*66 323*	*72 255*	*1 124*	*23 195*	*58*	*OBS99*
2000	*95 694*	*65 933*	*72 404*	*1 138*	*23 373*	*58*	*linear interpolation*
2001	*95 743*	*65 543*	*72 553*	*1 151*	*23 552*	*58*	
2002	*95 793*	*65 154*	*72 702*	*1 165*	*23 730*	*57*	
2003	*95 842*	*64 764*	*72 850*	*1 179*	*23 908*	*57*	
2004	*95 891*	*64 374*	*72 999*	*1 193*	*24 086*	*57*	
2005	*95 941*	*63 984*	*73 148*	*1 206*	*24 264*	*57*	
2006	*95 990*	*63 595*	*73 297*	*1 220*	*24 442*	*56*	
2007	*96 039*	*63 205*	*73 446*	*1 234*	*24 620*	*56*	*OBS07*
2008	*96 053*	*62 958*	*73 547*	*1 234*	*24 752*	*56*	*linear interpolation*
2009	*96 067*	*62 711*	*73 648*	*1 234*	*24 884*	*56*	
2010	*96 080*	*62 465*	*73 749*	*1 233*	*25 017*	*56*	
2011	*96 094*	*62 218*	*73 851*	*1 233*	*25 149*	*55*	
2012	*96 107*	*61 971*	*73 952*	*1 233*	*25 281*	*55*	*LU12*
2013	*96 121*	*62 035*	*73 742*	*1 233*	*25 414*	*55*	*linear extrapolation*
2014	*96 135*	*62 189*	*73 443*	*1 233*	*25 546*	*55*	
2015	*96 148*	*61 868*	*73 618*	*1 233*	*25 678*	*55*	
Trend 1990-2015	*3.03%*	*-9.73%*	*1.93%*	*-9.78%*	*14.92%*	*-93.26%*	*NA*
Trend 2013-2015	*0.03%*	*-0.27%*	*-0.17%*	*-0.03%*	*1.04%*	*-0.67%*	*NA*
Trend 2007-2012	*0.07%*	*-1.95%*	*0.69%*	*-0.06%*	*2.69%*	*-1.65%*	*NA*
Share in 1990	*36.09%*	*26.50%*	*27.93%*	*0.53%*	*8.64%*	*0.31%*	*NA*
Share in 2015	*37.18%*	*23.92%*	*28.47%*	*0.48%*	*9.93%*	*0.02%*	*NA*

Table 1-13 represents the land cover surfaces in ha for the different LULUCF categories, for the period from 1989 to 2015.

The LU maps (based on OBS89, OBS99, OBS07 and RE12) are highlighted in yellow. The years in between have been estimated by linear interpolation.

6.1.4 Completeness

Table 1-14 gives an overview of the IPCC categories included under CRF Sector 5 and provides information on the status of emission estimates of all subcategories.

Table 6-14 – Overview of sub-categories of CRF Sector 4 – LULUCF: status of emission estimates for CO_2, CH_4 and N_2O

GHG source & sink category	Description	Status		
		Net CO_2	CH_4	N_2O
4A1	forest land remaining forest land	X	NO	NO
4A2	land converted to forest land	X	NO	NO
4B1	cropland remaining cropland	X	NO	IE*,X
4B2	land converted to cropland	X	NO	X
4C1	grassland remaining grassland	IE**, X**	NO	NO
4C2	land converted to grassland	X	NO	X
4D1	wetlands remaining wetlands	NE,NO	NO	NO
4D2	land converted to wetlands	X	NO	X
4E1	settlements remaining settlements	NE	NE	NE
4E2	land converted to settlements	X	NE	X
4F1	other land remaining other land			
4F2	land converted to other land	X	NO	X
4G	Other (Harvested wood products)	IO	NO	NO

Note: a **X** indicates that emissions from this sub-category have been estimated, the grey shaded cells are those also shaded in the CRF tables.
(*) CO_2 emissions from cropland remaining cropland due to land use change from perennial to annual cropland are included in agricutlure
(**) CO_2 emissions from lime application on grassland are included in agriculture.
(**) emissions and removals from grassland remaining grassland have been estimated but they equal to zero, hence NO is being used in the CRF tables.

6.2 Forest Land (4A)

Luxembourg has some 96 148 ha of forests, covering about 37% of the country's area. The population is well situated with an average forest area of approximately 18 acres per person.

6.2.1 Category description

With regard to forest land, the annual net CO_2 emissions/removals of the reported period 1990-2015 range from -240 Gg CO_2 (removal) to -978 Gg CO_2 (removal). The most important sub-category is forest land remaining forest land (5.A.1), whereas land use changes to forests (5.A.2) and from forests (5.B.2 to 5.F.2) have only minor influence on the net CO_2 balance.

For the reported period 1990 to 2015, the total annual net CO_2 removals (biomass and soil) from land use changes to forest range from about -306 Gg CO_2 to -101 Gg CO_2 (Table 1-15).

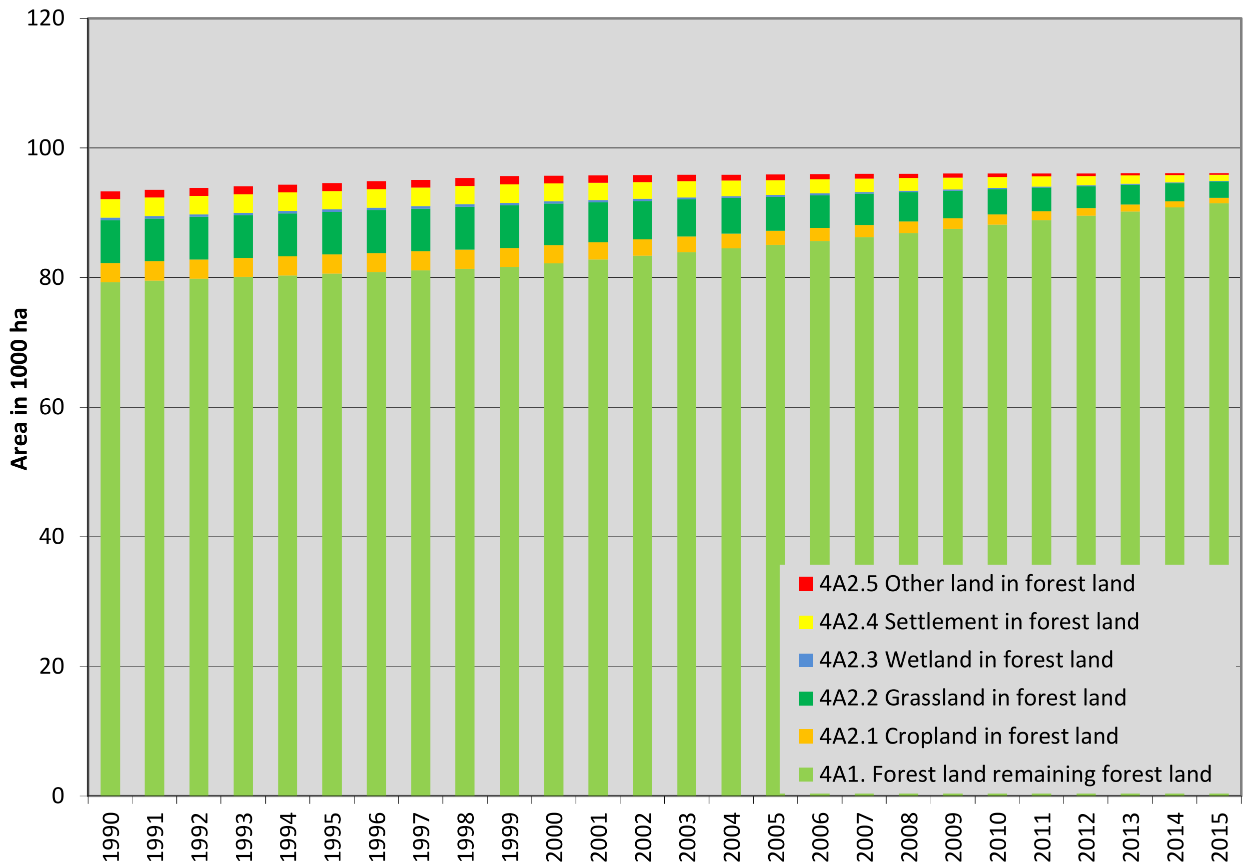
Table 6-15 – CO_2 removals/emissions from IPCC category 4A – Forest Land from 1990-2015

	4A - Forestland *Greenhouse gas emissions/removals (Gg CO_2 e)*							
Year	**4A Total Forest Land**	**4A1 FL remaining FL**	**4A2 Land -> FL**	**4A2.1 Cropland -> FL**	**4A2.2 Grassland -> FL**	**4A2.3 Wetland -> FL**	**4A2.4 Settlement -> FL**	**4A2.4 Other land -> FL**
1990	*- 239.80*	*65.90*	*- 305.70*	*- 61.11*	*- 108.59*	*- 13.56*	*-78.17*	*-44.28*
1991	*- 517.04*	*- 211.34*	*- 305.70*	*- 61.11*	*- 108.59*	*- 13.56*	*-78.16*	*-44.28*
1992	*- 846.22*	*- 540.52*	*- 305.70*	*- 61.11*	*- 108.59*	*- 13.56*	*-78.16*	*-44.28*
1993	*- 941.29*	*- 635.59*	*- 305.70*	*- 61.11*	*- 108.59*	*- 13.56*	*-78.16*	*-44.28*
1994	*- 752.10*	*- 446.40*	*- 305.70*	*- 61.11*	*- 108.59*	*- 13.56*	*-78.16*	*-44.28*
1995	*- 855.18*	*- 549.48*	*- 305.70*	*- 61.10*	*- 108.58*	*- 13.56*	*-78.16*	*-44.28*
1996	*- 895.60*	*- 589.90*	*- 305.70*	*- 61.10*	*- 108.58*	*- 13.56*	*-78.16*	*-44.28*
1997	*- 978.33*	*- 672.64*	*- 305.70*	*- 61.10*	*- 108.58*	*- 13.56*	*-78.16*	*-44.28*
1998	*- 862.75*	*- 557.06*	*- 305.69*	*- 61.10*	*- 108.58*	*- 13.56*	*-78.16*	*-44.28*
1999	*- 960.46*	*- 654.77*	*- 305.69*	*- 61.10*	*- 108.58*	*- 13.56*	*-78.16*	*-44.28*
2000	*- 839.18*	*- 536.37*	*- 302.81*	*- 60.89*	*- 109.87*	*- 12.94*	*-77.04*	*-42.08*
2001	*- 851.37*	*- 560.49*	*- 290.88*	*- 58.15*	*- 105.99*	*- 12.33*	*-74.50*	*-39.90*
2002	*- 853.26*	*- 574.34*	*- 278.92*	*- 55.42*	*- 102.11*	*- 11.71*	*-71.97*	*-37.72*
2003	*- 816.38*	*- 549.43*	*- 266.95*	*- 52.67*	*- 98.22*	*- 11.10*	*-69.43*	*-35.53*
2004	*- 820.63*	*- 565.67*	*- 254.96*	*- 49.93*	*- 94.32*	*- 10.48*	*-66.89*	*-33.34*
2005	*- 775.54*	*- 532.59*	*- 242.95*	*- 47.18*	*- 90.41*	*- 9.87*	*-64.34*	*-31.15*
2006	*- 693.96*	*- 463.03*	*- 230.93*	*- 44.42*	*- 86.50*	*- 9.25*	*-61.80*	*-28.96*
2007	*- 614.54*	*- 395.66*	*- 218.89*	*- 41.66*	*- 82.58*	*- 8.63*	*-59.25*	*-26.76*
2008	*- 576.54*	*- 370.06*	*- 206.48*	*- 38.88*	*- 79.00*	*- 7.97*	*-56.07*	*-24.56*
2009	*- 552.46*	*- 360.86*	*- 191.60*	*- 35.89*	*- 73.95*	*- 7.30*	*-52.11*	*-22.36*
2010	*- 234.52*	*- 57.82*	*- 176.70*	*- 32.89*	*- 68.89*	*- 6.63*	*-48.14*	*-20.16*
2011	*- 355.02*	*- 193.37*	*- 161.65*	*- 29.86*	*- 63.76*	*- 5.95*	*-44.14*	*-17.94*
2012	*- 441.43*	*- 294.82*	*- 146.61*	*- 26.83*	*- 58.64*	*- 5.28*	*-40.13*	*-15.73*
2013	*- 615.66*	*- 484.10*	*- 131.57*	*- 23.81*	*- 53.51*	*- 4.61*	*-36.13*	*-13.51*
2014	*- 535.99*	*- 419.46*	*- 116.52*	*- 20.78*	*- 48.38*	*- 3.94*	*-32.13*	*-11.29*
2015	*- 479.66*	*- 378.19*	*- 101.48*	*- 17.75*	*- 43.25*	*- 3.26*	*-28.13*	*-9.08*
Trend 1990-2015	*100.02%*	*-673.90%*	*-66.81%*	*-70.95%*	*-60.17%*	*-75.95%*	*-64.01%*	*-79.50%*
Trend 2013-2015	*-22.09%*	*-21.88%*	*-22.87%*	*-25.43%*	*-19.17%*	*-29.21%*	*-22.15%*	*-32.79%*

The net carbon stock changes in forest biomass (sub-category 4.A.1) have a major impact on the overall results in sector 4. These changes vary considerable between single years. The reason is that the figures for annual harvest of forest biomass and to a lesser extend forest area differ significantly year by year. The annual harvest will be analysed in chapter 1.2.4.1.1 (page 430) is influenced by timber demand and prices as well as salvage logging after windfalls. The influence of those factors on the annual variations in the CO_2 net removals of this sector will be explained in the same chapter.

The variation within the time trend for LUCs to forest land is mainly due to the change of LUC areas and its composition of previous land use types across the time series. Figure 1-5 gives an overview of the LUCs to and from forests from 1970 and 1990 on, respectively. LUC areas are in the LUC subcategory for a transition period of 20 years starting 20 years before 1990.

Figure 6-5 – Trend of forest land and LUC to forest land (20 year conversion period) from 1990-2015



6.2.2 Information on approaches used for representing land areas and on land-use databases used for the inventory approach

In Luxembourg statistical data about forests are established and updated by the Nature and Forest Administration (Administration de la Nature et des Forêts (ANF)) of the Ministry of sustainable Development and Infrastructures. The forest inventory is partly based on aerial photography and partially based on territorial measurements (field-work).

The forest area comprises all territories as described in Table 1-16 and in accordance to the definition provided by FAO 2000.

Table 6-16 - Definition of forest as applied during forest inventory

Total forest area	Forest	Land with tree crown cover (or equivalent stocking level) of more than 10 % and area of more than 0.50 ha. The trees should be able to reach a minimum height of 5 m at maturity in situ. Young natural stands and all plantations established (0.1 – 0.5 ha) for forestry purposes which have yet to reach a crown density of 10 % or tree height of 5 m are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked as a result of human intervention or natural causes but which are expected to revert to forest.
	Grove	Group or cluster of trees with an area of 0.05 – 0.50 ha with a crown density of 10 % and where tree height potentially reached 5 m at adult stage.
	Other wooded land	Land either with a crown cover (or equivalent stocking level) of 5-10 percent of trees able to reach a height of 5 m at maturity in situ; or a crown cover (or equivalent stocking level) of more than 10 percent of trees not able to reach a height of 5 m at maturity in situ (e.g. dwarf or stunted trees); or with shrub or bush cover of more than 10 percent.
	Other land in forest areas	Area without tree cover which are enclosed, partially enclosed, or even attached to one side to a forest area and which have a surface area > 0.5 ha (pond, clearing, fallow land…)

The total forest area estimated during the second forest inventory (NFI 2 2010) for the year 2010 is 92 150 ha and is subdivided in the following types of forests:

- hardwood forests: 58 050 ha: 63 %
- coniferous forest (spruce, pin, douglas *etc.*) 27 250 ha: 30 %
- other forested (shrubs, forest roads, quarries, clear cuttings, *etc.*) 6 850 ha: 7 %

Figure 6-6 – Example of calculation method of forest area according to forest inventory

The forest inventory is a periodic survey of permanent forest sample plots based on a randomised systematic grid sample design. Each grid has a dimension of 1 000 m * 500 m and this grid density equates to 5 200 points nationally, each representing 50 ha. If a point on the grid is considered as being a forest (use of aerial photography) the equivalent of 50 ha are added to the forest area. In the image shown here above the forest area is estimated at 400 ha (8 points).

Figure 6-7 – Calculation method of forest area according to LUC method

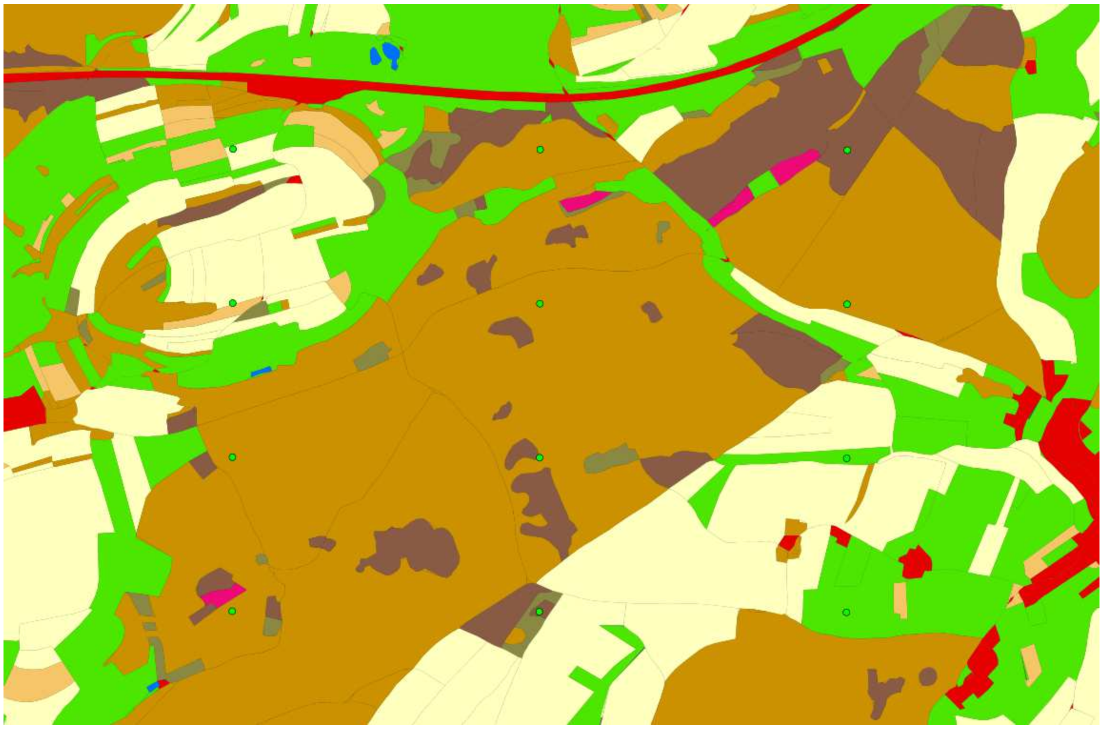


Figure 1-7 shows the same portion of land as Figure 1-6 but with the LUC method applied and based on occupational soil maps and satellite as well as aerial photography. The increased level of detail of the LUC method can be appreciated by comparing both figures.

It is important to highlight that both, the occupational soil maps, as well as the NFI, provide data on distribution of deciduous and coniferous forests. The assumption, at this point, is taken that the data of type of forest is more reliable from the forest inventory and hence the total forest areas of the occupational soil maps have been aggregated and redistributed to coniferous forests and deciduous forest according to the percentages of those types of forests from the NFI. The occupational soil maps do however provide data on land use changes from and to, either coniferous, deciduous and mixed forests. This information can however not be used for consistency reasons as the emission factors of biomass growth, harvest data, carbon stock etc are all based on the NFI. Instead the assumption is taken that land use changes to and from the different forest types are randomly distributed and reflect the species distribution of the NFI.

6.2.3 Land-use definitions and the classification systems used and their correspondence to the LULUCF categories

The LU89, LU99, LU07 and LU12 land use maps are the main data providers for the greenhouse gas reporting of IPCC category forestland. The National Forest Inventory (NFI) of Luxembourg is the main data provider for the development of carbon stock factors. Consequently and for reason of consistency, the applied forest definition for the reporting follows the definition used within the NFI and the OBS maps. The selected parameters are:

Land Use Class	Definition
ForestLand	All forest and wooded land according to the FAO TBRA2000 definition: • Minimum land area: 0.5 ha • tree crown cover >= 10 % • tree height >= 5 m. In the geodata set, Forest land has been sub-divided into the forest types as defined below.
Conifers:	Including all forest land with > 10 % crown cover and on which more than 75 percent of the tree crown cover consists of coniferous species.
Deciduous:	Including all forest land with > 10 % crown cover and on which more than 75 percent of the tree crown cover consists of broadleaved species
Mixed (coniferous and deciduous):	with > 10 % crown cover and less than 75 % crown cover of one class.

Permanently unstocked basal areas that are directly connected with forest in terms of space and forestry enterprise and contribute directly to its management (such as forest hauling systems, wood storage places, forest glades, forest roads) also represent forests. Areas which are used in short rotation with a rotation period of up to thirty years as well as forest arboretums, forest seed orchards, Christmas tree plantations and plantations of woody plants for the purpose of obtaining fruits such as walnut or sweet chestnut do not account as forests but represent cropland. Rows of trees (except shelter belts for wind protection) and areas with woody plants in a park structure are not forest land.

6.2.4 Methodological issues

6.2.4.1 Forest Land remaining Forest Land (4A1)

6.2.4.1.1 Change of carbon stock in living biomass

For the changes in living biomass, the IPCC Guidelines 2006 Tier 2 approach (biomass gain-loss method) was used with country-specific estimated activity data and emission/removal factors extracted from the national forest inventory.

The calculation of gains in living biomass is mainly based on the results from the two forest inventories carried out in 2000 as well as in 2010. The data extracted from the combination of those two inventories allowed defining country specific values for above- and below-ground biomass growth, wood removal, dead wood as well as country-specific biomass conversion and expansion factors.

The methodology employed to estimate those country-specific values is described in (Alderweireld, 2015). The calculation of biomass volume stock is based on new research (compared to the calculation method described in the official forest inventory publication) and hence the method will be briefly described here below:

The merchantable volume of wood (for standing trees as well as for dead wood) is estimated with the equations of (Dagnelies, Palm, & Rondeux, 2013) which have been defined for 12 tree species. Those equations give the volume of wood from the main trunk and main branches up to a diameter of 7 cm.

The above-ground biomass is calculated with the following formula:

$$G_{W(ag)} = V \cdot BEF_{ag} \cdot WBD$$

where :

$G_{W(ag)}$= average annual above-ground biomass growth (excluding leaves) for a specific woody vegetation type (tonnes d.m. $ha^{-1}yr^{-1}$)

V = volume of merchantable wood calculated according to (Dagnelies, Palm, & Rondeux, 2013) (m^3 ha^{-1})

BEF_{ag} = biomass expansion factor for above-ground biomass (Deleuze, et al., 2014)

WBD = wood biomass density (tonnes d.m./m^3) (Wagenführ & Schreiber, 1985)

The BEF values were calculated from the work of (Deleuze, et al., 2014), which provides a formula to calculate total above ground biomass depending on height and diameter. The work of (Deleuze, et al., 2014) is based on the work of (Vallet, Dhôte, Le Moguédec, Ravart, & Pignard, 2006).

The below-ground biomass is calculated with the following formula:

$$G_{W(bg)} = V \cdot BEF_{bg} \cdot WBD$$

where :

$G_{W(bg)}$= average annual below-ground biomass growth (excluding leaves) for a specific woody vegetation type (tonnes d.m. $ha^{-1}yr^{-1}$)

V = volume of merchantable wood calculated according to (Dagnelies, Palm, & Rondeux, 2013) (m^3 ha^{-1})

BEF_{bg} = biomass expansion factor for below-ground biomass (Vande Walle, et al., 2005)

WBD = wood biomass density (tonnes d.m./m^3) (Wagenführ & Schreiber, 1985)

CF = carbon fraction of dry matter, tonne C (tonne d.m.)$^{-1}$

With:

$$BEF_{bg} = BEF_{ag} \cdot R$$

where :

R = ratio of below-ground biomass to above-ground biomass, in tonne d.m. (Vande Walle, et al., 2005)

BEF_{ag} = biomass expansion factor for above-ground biomass

The IPCC 2006 guidelines only use a biomass expansion factor and a below-ground to above-ground ratio. The study referenced here above introduces a new variable in order to determine below-ground biomass directly from volume of merchantable wood. Essentially the calculations are the same as the one under the IPCC guidelines 2006 but are more suitable to the methods employed by the NFI.

In order to estimate the gain in biomass due to biomass growth for *5A1 - Forest Land Remaining Forest Land*, country specific biomass increment factors have been generated by comparing the biomass increase between the two inventories on the same trees. This methodology has also allowed calculating growth factors for different age categories as can be seen on Figure 1-8. The age categories between 80 and 160 years (mainly for coniferous forests) are however not based on enough samples so that they cannot be seen as statistically reliable. The same applies to the age category 61-80 for deciduous trees which are also underrepresented.

The carbon content used in the calculations is the default value: 0,47 CF = carbon fraction of dry matter, tonnes C (tonne d. m.)$^{-1}$.

Figure 6-8 – country-specific biomass growth by forest type and by age (source: NFI)

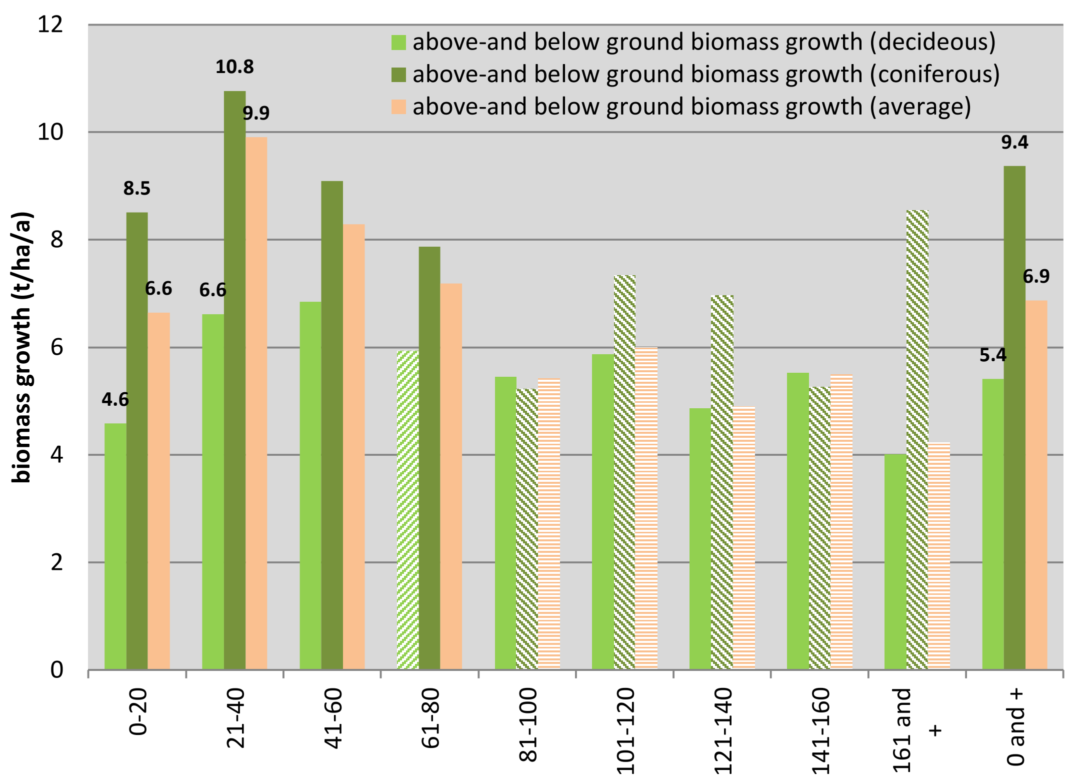


Table 6-17 – country-specific values for above- and below ground biomass increment factors (tonnes d.m. ha^{-1} yr^{-1})

		above-ground biomass growth	below-ground biomass growth
deciduous	all ages	4.4	1.0
	age 0-20	3.8	0.8
	age 21-40	5.4	1.2
coniferous	all ages	7.8	1.5
	age 0-20	7.1	1.4
	age 21-40	9.0	1.8
average	all ages	5.7	1.2
	age 0-20	5.5	1.1
	age 21-40	8.3	1.6

The growth factors used for the purpose of the inventory are summarised in **Table 1-17**.

In order to estimate the carbon loss due to drain of living biomass (wood and fuelwood removal) stemwood drain data has to be converted in biomass. The data from the forest inventory (Alderweireld, 2015) has been used to define country specific biomass conversion and expansion factors by taking into account the number and type of trees found in coniferous forests as well as deciduous forest.

Table 6-18 – country-specific biomass conversion factor and ratio of below-ground to above-ground biomass used for the calculation of wood removal

	$BCEF_R$	R
Deciduous forests	0.74	0.22
Coniferous forests	0.55	0.20
average	0.68	0.21

Data on wood harvest is derived from the statistics of the ANF (Administration de la Nature et des Forêts) as well as from the data extracted from the two consecutive forest inventories. The statistical data collected by the ANF is limited to the wood harvest of public forest and does not include wood harvest of private forests. Furthermore, ANF harvest statistics do not include biomass drain due to mortality (fallen dead trees remaining at site), but the drain according to the forest inventories includes this stemwood loss. In the previous submissions the wood harvest from private forests was simply estimated by using the same harvest rates as public forests and extrapolating it to the forest area of public forests (often with a simple 50/50 ratio). With the completion of the second forest inventory the following data has however become available:

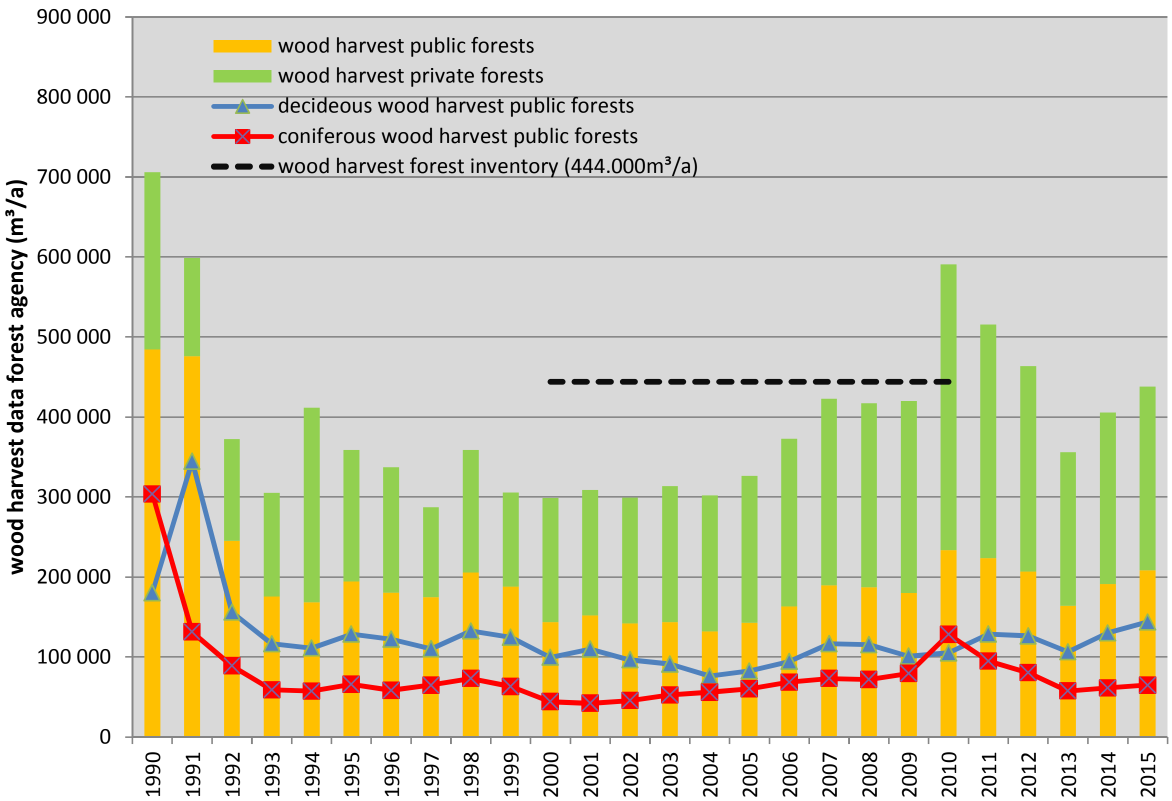
) Stemwood drain from public deciduous forests: 4.8 m^3/ha/a
a) Stemwood drain from private deciduous forests: 3.3 m^3/ha/a
b) Stemwood drain from public coniferous forests: 8.7 m^3/ha/a

c) Stemwood drain from private coniferous forests: 8.7 m^3/ha/a

d) Proportion of public deciduous, public coniferous, private deciduous and private coniferous forests for the years 2000 and 2010

e) Average annual stemwood drain measured during NFI between 2000 and 2010: 444 000 m^3/a

Figure 6-9 – stemwood drain from public forests and estimated stemwood drain from private forests

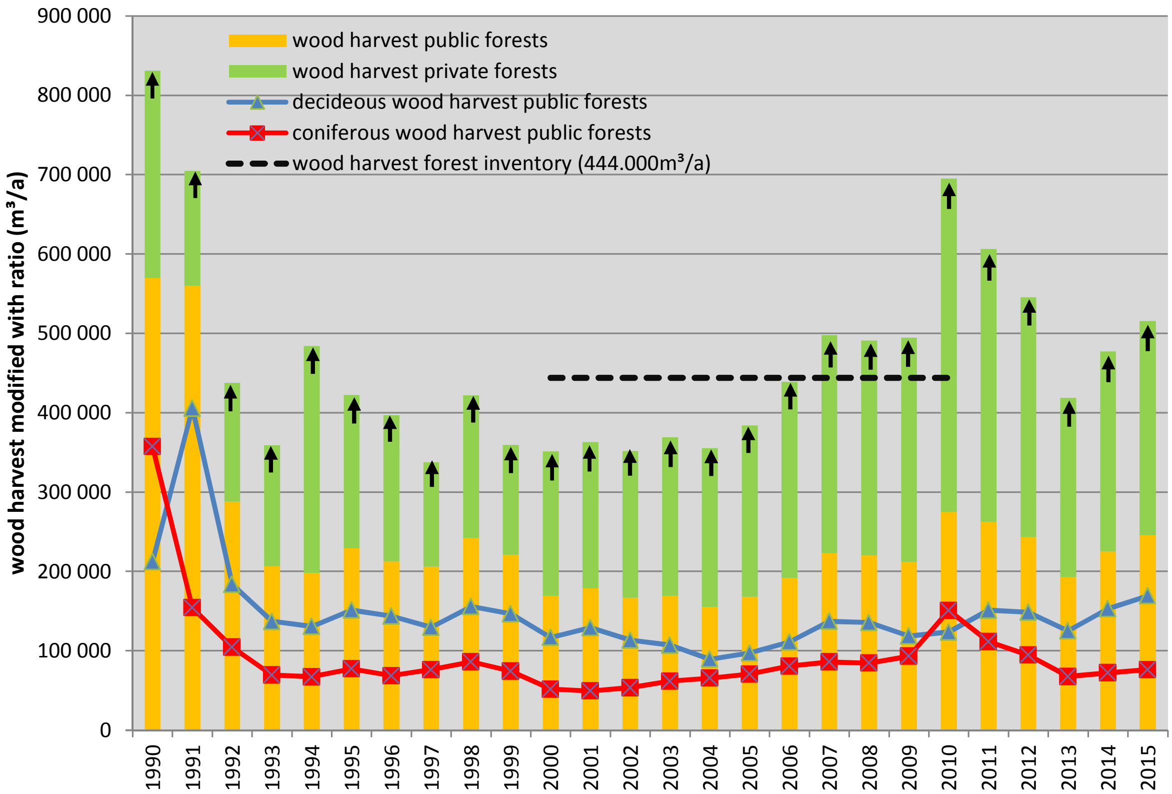


The following figure shows the yearly wood drain from public forests (yellow bars) as collected by the ANF. The green bars show the estimated wood drain from private forests estimated with the specific ratios of wood drain and forest distribution as collected during the forest inventory. The peaks 1990 and 1991 and the subsequent fall in wood drain can be explained through the salvage logging after the windstorm of 1990. The peak in 2010 has been traced back to the change of forest practice in one northern commune and also because of salvage logging after the windstorm Xinthia. Considering that this increase was mainly happening in coniferous wood (see red line) the estimated wood harvest of private forests was strongly affected as the area of private coniferous forest is twice as high as public coniferous forests and the average harvest rate out of coniferous forests is very high (8.7 m^3/h/a).

The black dotted line shows the total average wood drain as estimated from the forest inventory. Compared to the average wood drain compiled with the methods described here above it is possible to see that the average wood drain between 2000 and 2010 is lower (377 000 m^3/a) than the average measured during the forest inventory (444 000 m^3/a). The difference is not very high (18 %) and can easily be explained (wood loss during harvest, wood (> 7cm in diameter) remaining as dead wood in forest, different time periods for data collection, estimation of wood harvest from public forests). Hence the whole time series of wood harvest data (1990-2014) was amended (+18%) to match the wood harvest rate of the forest inventory. The reasons to align the data collected from the ANF to the one from the forest inventory are the following:

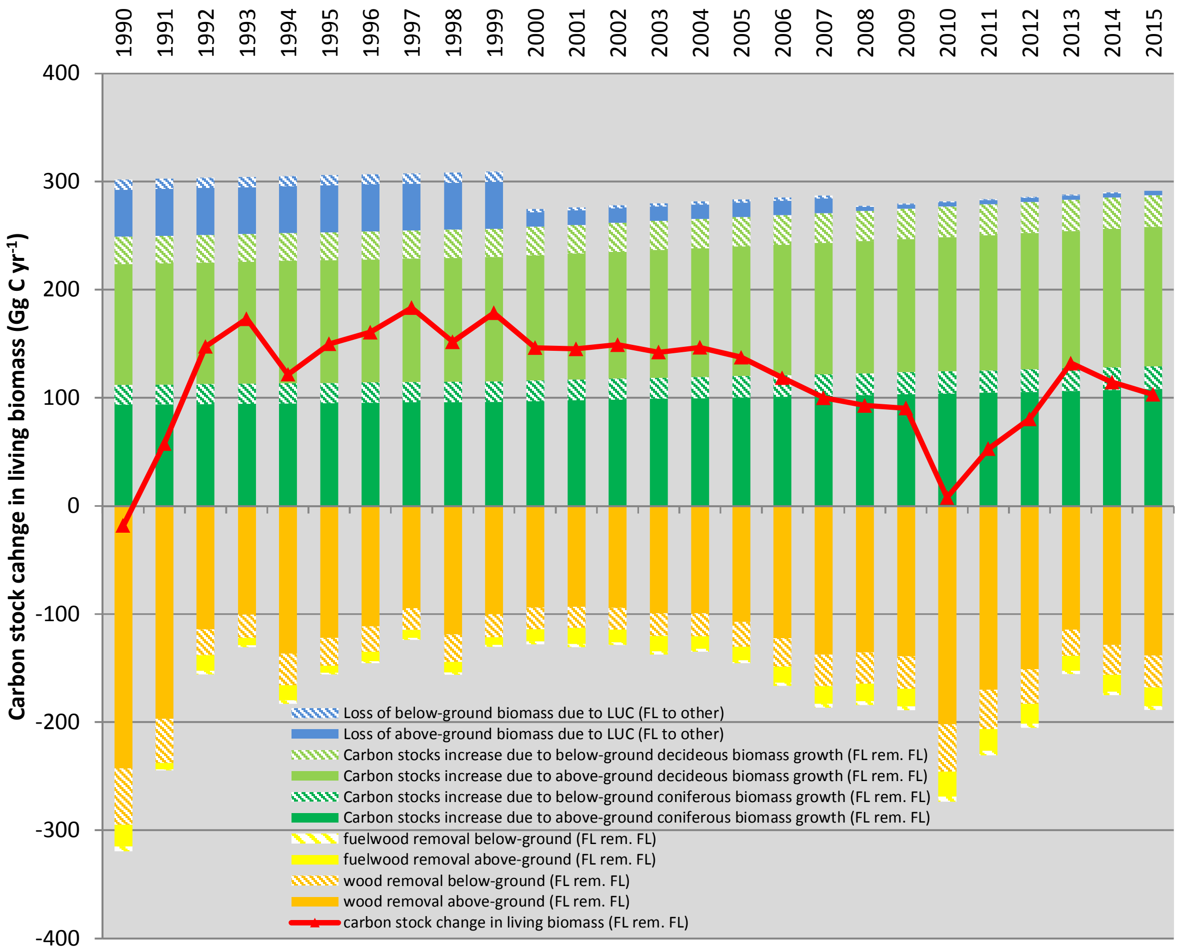
- The data collected from the inventory is more reliable as it is based on a more systematic approach
- The calculation of the total biomass removed is based on country specific biomass expansion and conversion factors (described here above) that are based on the assumption that all wood >7 cm in diameter is removed. Forest practices in public forest limit wood removal to wood with a diameter > 10 cm.

Figure 6-10 – amended time series of wood harvest (alignment with average wood harvest from forest inventory)



It is also important to note that the data on wood harvest shown Figure 1-10 also includes the biomass removed during conversion of forestland in other land use. According to IPCC Guidelines 2006 Chapter 4.2.1.3 the definition of wood removals and fuelwood removals state clearly that "wood removal from Forest Land Remaining Forest Land and wood removal coming from Forest Land conversion to other uses should be separated". In order to avoid double counting the data of carbon loss due to biomass loss from forest land conversion to other land use (from chapters 1.3.4.2.1 & 1.4.4.2 & 1.5.4.2 & 1.6.4.2 & 1.7.3.2.1) has been subtracted from the carbon loss due to wood removal. In Figure 1-11 it is shown as a carbon gain in order to make it visible within the chart.

Figure 6-11 – change of carbon stock living biomass (forestland remaining forestland)



The practice of taking fuelwood as tree parts is only used marginally in Luxembourg (expert judgement) and thus it is considered that all fuelwood is removed as whole aboveground tree parts. With regards to natural disturbances it is assumed that during previous disturbances all stemwood was removed as part of salvage logging.

6.2.4.1.2 Change of carbon stock in soil

For the changes in soil carbon stock the IPCC GPG 2006 Tier 1 approach was used assuming that no changes in the soil carbon stock occur.

6.2.4.1.3 Change of carbon stock in dead wood

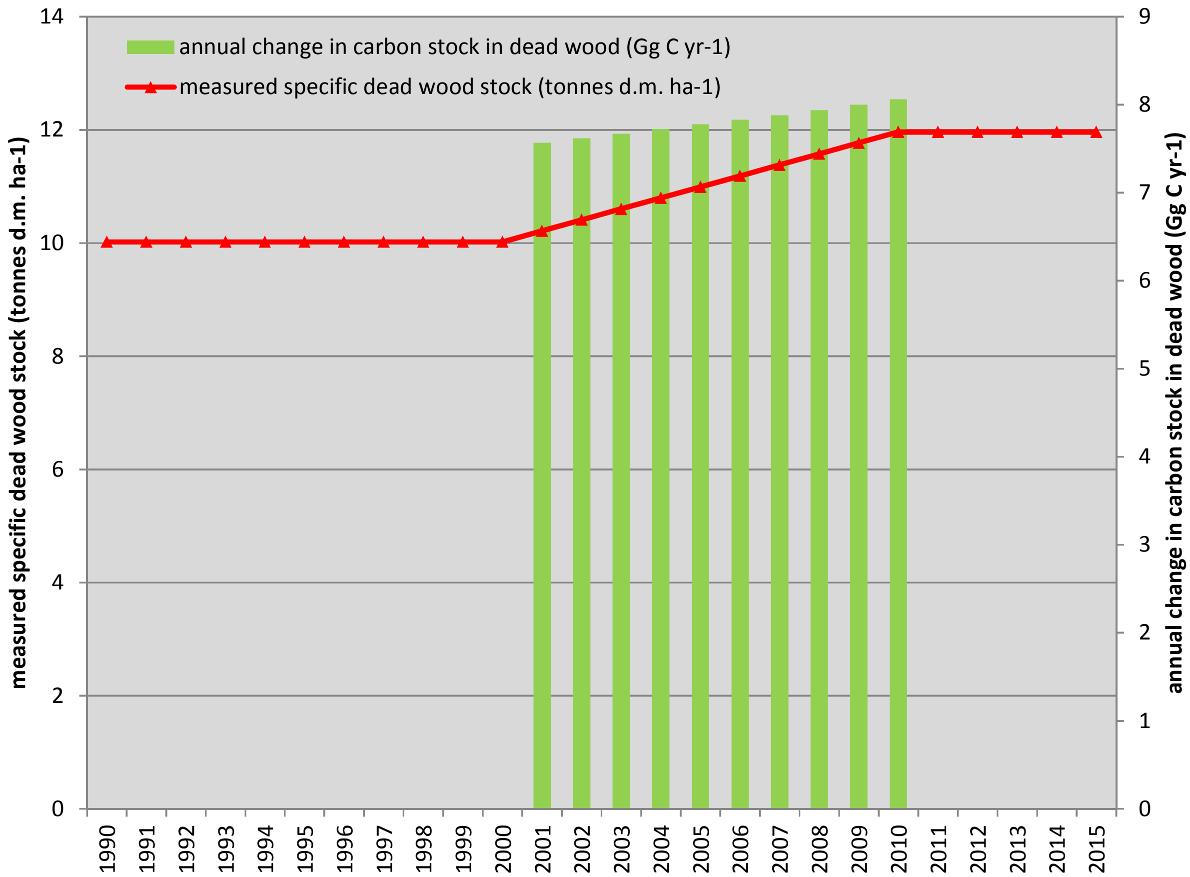
In order to take into account changes in dead wood, the IPCC GPG Tier 2 approach (stock-difference approach) was used. Data on dead wood stocks is available at two time-points (NFI 1 – year 2000 and NFI 2 – year 2010). Data was collected on dead wood with a diameter greater than 7 cm and older than 3 years (unlikely to be harvested). In order to estimate the biomass for dead wood the biomass expansion factor were not applied which means that small branches of dead wood are not considered. The degree of decomposition influences the quantity of biomass but is not considered in this study as no data on decomposition has been collected and that the current literature does not provide reliable calculation methods at this moment in time to take into account the degree of decomposition. Over the last years the forest agency has pursued an active policy to increase the dead wood in public forest. This has led to an increase in dead wood in the forest as can be seen in **Table 1-19**.

Table 6-19 –values for dead wood by inventory year (tonnes d.m. ha^{-1} yr^{-1})

	2000	2010
Dead wood on floor	6.3	7.0
Dead wood standing	3.8	5.0

The calculation of carbon stock difference is based on the IPCC GPG formulas on stock-difference and the results can be seen in Figure 1-12.

Figure 6-12 – change of carbon stock in dead wood



For the years before (1990-2000) and after (2011-2015) the two inventories it was assumed that no change in dead wood stock change occurred. This is a conservative approach as it is very likely that the new harvesting practice (no harvest of wood < 10 cm) will lead to a further increase in dead wood for years to come.

6.2.4.1.4 Change of carbon stock in litter

For the changes in carbon stock in litter the IPCC GPG Tier 1 approach was used assuming that no changes in the litter carbon stock occur. Unfortunately no data on litter C stock changes has so far been collected in Luxembourg so that this hypothesis could not be verified.

6.2.4.2 Land Use Changes to Forest Land (4A2)

6.2.4.2.1 Change of carbon stock in living biomass of land converted to forest land

The method follows the Tier 2 IPCC GPG approach with default transition periods of 20 years for LUC and country specific data for biomass increase factors. It is assumed that no wood removal occurs in forest less than 20 years old.

For the calculation of annual change in carbon stocks of living biomass of land converted to forestland the IPCC GPG 2006 LULUCF Tier 1 method equation 2.15 and 2.16 was applied:

$$\text{Annual change in carbon stock in biomass} = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L$$

$$\Delta C_{CONVERSION} = \sum_i \{(B_{AFTER_i} - B_{BEFORE_i}) \cdot \Delta A_{TO\_OTHERS_i}\} \cdot CF$$

where :

ΔC_G = annual change in carbon stocks in biomass due to growth on land converted to another land-use category (The biomass increment factor for *4.A.2.1 - Land converted to Forestland* is described under § 1.2.4.1. The first age class (0-20) values (**Table 1-17**) for the annual increment are being used: above-ground biomass growth of 5.5 tonnes d.m. ha-1 yr-1 and below-ground biomass growth 1.1 tonnes d.m. ha-1 yr-1 .)

$B_{AFTER(i)}$ = stocks on land type i immediately after conversion, tonnes d.m. ha^{-1} (default value = 0).

$B_{BEFORE(i)}$ = stocks on land type i before conversion, tonnes d.m. ha^{-1} (value for carbon stock of woody biomass before conversion depending on land use: see **Table 1-20** as well as **Table 1-21**)).

ΔC_L = annual decrease in biomass carbon stocks due to losses from harvesting, fuel wood gathering and disturbances on land converted to other land-use category, in tonnes C yr^{-1} (default value = 0).

$\Delta T_{TO\_OTHERS(i)}$ = area of land use converted to another land-use category in a certain year, ha yr^{-1}.

CF = carbon fraction of dry matter, tonne C (tonne d.m.)$^{-1}$.

i = type of land use converted to another land-use category

Table 6-20 –biomass stock for different land use categories (tonnes C ha^{-1})

	Pool	value	Reference
Cropland annual	below-ground	5.0	Table 5.9 IPCC GPG (LULUCF 2006)
Cropland perennial	above-ground	6.4	See below
Forestland	above-ground	98.4	NFI
Forestland	below-ground	21.3	NFI
Grassland	above- and below-ground	6.3	Table 6.4 IPCC GPG (LULUCF 2006)
Wetlands	N/A	0.0	Tier 1
Settlements	above-ground	4.3	section 1.6.4.2
Other land	N/A	0.0	Tier 1

Table 1-20 summarises the biomass stock factors for the different land use categories that are being lost during land use change to forestland. The biomass decrease factor for *4.A.2.1 – Annual cropland converted to Forestland* is 5.0 t C/ha and derives from Table 5.9 of the IPCC GPG (LULUCF 2006, Tier 1 default value). The biomass decrease factor for *4.A.2.2 - Grassland converted to Forestland* is 6.3 t C/ha and derives from Table 6.4 of the IPCC GPG (LULUCF 2006, Tier 1 default value of 13.5 tonnes d.m ha^{-1}). As the distinction between below-and above-ground biomass at this level is not always very clear and in order to simplify the calculations all the biomass stock factors are being considered as above-ground. For wetland and other land the default value for biomass stock is set to 0.

According to the data from ASTA vineyards constitute 93 % of the perennial cropland in Luxembourg and it seems justified to calculate a country-specific biomass stock factor for perennial cropland (as was recommended during audit (FCC/ARR/2014/LUX).

Table 6-21 –biomass decrease factors for perennial cropland (tonnes C ha^{-1})

	% of perennial cropland	Value	Reference
Vineyards	94	2.64	Germany/Switzerland
orchards	6	63.00	IPCC GPG Table 5.1
Perennial cropland (average)	100	6.41	/

The biomass stock factor for perennial cropland used in Luxembourg is a weighted average of vineyards specific values used by neighbouring countries (Germany – NIR 2014: 1.66 Mg C ha^{-1} and Switzerland – NIR 2015: 3.61 Mg C ha^{-1}) and the default IPCC GPG value used typically for orchards (63.0 Mg C ha^{-1}).

6.2.4.2.2 Change of carbon stock in soil of land converted to forest land

Very recently (October 2014), ASTA (Administration des Services Techniques de l'Agriculture) presented two new studies on the carbon content and stocks of different soil types in Luxembourg ("Mapping Topsoil Organic Carbon Content in the Grand-Duchy of Luxembourg" and "Mapping Topsoil Organic Carbon Stocks in the Grand-Duchy of Luxembourg"). While the first study provides detailed information on the carbon content in soils of Luxembourg (covering 90% of the territory and per land use type), the second study assesses the amount of carbon stored in soils of a given area by taking into account the soil density, soil depth (0-30 cm), and the proportion of fine earth to the total soil mass.

Table 6-22 – Carbon soil stocks per land use and soil type (t C/ha) in Luxembourg

		Carbon soil stocks per land use and soil type (t C/ha)						
Soil type	Total (ha)	Cropland (Annual Cropland)	Grassland	Forestland	Vineyard (Perennial cropland)	wetland	settlement	other land
Oesling	70'942	91.5	89.2	132.2	71.0	0.0	43.2	0.0
Buntsandstein	10'495	66.7	82.8	112.1	73.5	0.0	43.2	0.0
Dolomies du Muschelkalk	11'562	85.5	112.1	117.0	77.9	0.0	43.2	0.0
Calcaires du Bajocien	2'916	75.2	122.0	111.5	77.7	0.0	43.2	0.0
Grès de Luxembourgs	25'060	50.7	83.3	80.6	76.2	0.0	43.2	0.0
Dépôts limoneux sur	22'382	58.6	99.4	95.7	75.1	0.0	43.2	0.0

Grès								
Argiles du Lias inf. et moyen	27'673	69.8	121.6	95.2	75.7	0.0	43.2	0.0
Argiles lourdes du Keuper	21'966	67.7	121.3	102.6	76.0	0.0	43.2	0.0
Argiles lourdes des schistes bitumineux	6'677	88.2	145.7	104.8	NA	0.0	43.2	0.0
Autres	12'824	80.7	110.8	126.6	74.9	0.0	43.2	0.0

According to GPG the use of country-specific values for carbon content changes during land-use change will be based “on paired-plot comparisons representing converted and unconverted lands”, “where all factors other than land-use history are as similar as possible” (p.3.130). As the soil carbon stock is provided per land use and per soil type the soil carbon it was agreed during the audit of 2014 that stock changes should be computed for each land-use transition within a given soil type. This would be in accordance with the GPG: soil type indeed is an acceptable proxy for “all factors other than land-use history” as further covariates cannot be included in the analysis.

One method of using those country specific values would be to attribute the relevant soil-type-specific IEF to each soil-type specific land use change observed, based on the geographic coordinates of the observed land-use change. This would, however, be very time-consuming and not feasible with the dataset as it is available at the moment. Considering that the land use changes are homogeneously distributed throughout Luxembourg, the alternative method was chosen to compute a weighted average of soil-type-specific IEFs, where the soil carbon stock changes for each land-use transition within a given soil type is weighted by its area in Luxembourg:

$$\mathrm{IEF}(LUC_j) = \frac{\sum_i \mathrm{IEF}(LUC_j)_{\mathrm{st,i}} \cdot A_{st,i}}{\sum_i A_{st,i}}$$

$\mathrm{IEF}(\mathrm{LUC_j})$ = average yearly emission factor for carbon stock change in soil from land use change j (eg forestland in cropland)

$\mathrm{IEF}(\mathrm{LUC})_{\mathrm{st,i}}$ = yearly emission factor for carbon stock change in soil from land use change j for a soil type i

$A_{\mathrm{st,i}}$ = area of soil type i

with:

$$\mathrm{IEF}(LUC_j)_{\mathrm{st,i}} = \frac{\mathrm{SOC}(LU_a)_{\mathrm{st,i}} - \mathrm{SOC}(LU_b)_{\mathrm{st,i}}}{\mathrm{transition_{period}}}$$

$\mathrm{IEF}(\mathrm{LUC})_{\mathrm{st,i}}$ = yearly emission factor for carbon stock change in soil from land use change j (eg CL->GL) for a soil type i

$\mathrm{SOC}(\mathrm{LU_{a,b}})_{\mathrm{st,i}}$ = soil organic content by land use type a or b and soil type i

$\mathrm{transition_{period}}$ = period where the change in carbon stock change is achieved (typically 20 years)

Numerical example first step: calculating the IEF for each land use transition in each soil type (example of Oesling)

$$\mathrm{IEF}_{\mathrm{CL}\rightarrow\mathrm{GL\_Oesling}} = \frac{\mathrm{SOC}_{\mathrm{CL}_{\mathrm{Oesling}}} - \mathrm{SOC}_{\mathrm{GL}_{\mathrm{Oesling}}}}{\mathrm{transition}_{\mathrm{period}}} = \frac{91.5 - 89.2}{20} = 0.115\ \mathrm{tC.\,ha}^{-1}.\,yr^{-1}$$

Second step: calculating the national average IEF for each land-use transition (this simplicity makes sense as Luxembourg justifies that D and AR is roughly equally distributed over its territory)

$$\mathrm{IEF}_{\mathrm{CL}\rightarrow\mathrm{GL\_national}} = \frac{\mathrm{IEF}_{\mathrm{CL}\rightarrow\mathrm{GL\_Oesling}} \times \mathrm{area}_{\mathrm{Oesling}} + \mathrm{IEF}_{\mathrm{CL}\rightarrow\mathrm{GL\_Buntsandstein}} \times \mathrm{area}_{\mathrm{Buntsandstein}} + \cdots}{\mathrm{area}_{\mathrm{Oesling}} + \mathrm{area}_{\mathrm{Buntsandstein}} + \cdots}$$

The calculation of all land use changes results in the following matrix:

Table 6-23 – land use change matrix for soil carbon emission factors (t C/ha*y)

from \ to	Forest land	Annual Cropland	Perennial Cropland	Grassland	Wetland	Settlement	Other land
Forest land	0	-1.784	-1.237	-0.476	-5.554	-3.393	-5.554
Annual Cropland	1.784	0	0.462	1.308	-3.770	-1.609	-3.770
Perennial Cropland	1.237	-0.462	0	1.517	-3.778	-1.616	-3.778
Grassland	0.476	-1.308	-1.517	0	-5.079	-2.917	-5.079
Wetland	5.554	3.770	3.778	5.079	0	2.162	0.000
Settlement	3.393	1.609	1.616	2.917	-2.162	0	-2.162
Other land	5.554	3.770	3.778	5.079	0.000	2.162	0

And thus the following increment factors were used for estimating the change of carbon stock in soil of land converted to forest land:

f) annual cropland converted to forestland: +1.784 t C/ha*y
g) perennial cropland converted to forestland: +1.237 t C/ha*y
h) grassland converted to forestland: +0.476 t C/ha*y
i) wetland converted to forestland: +5.554 t C/ha*y
j) settlements converted to forestland: +3.393 t C/ha*y
k) other land converted to forestland: +5.554 t C/ha*y

6.2.4.2.3 Change of carbon stock in dead wood and litter

In order to estimate the increase in dead wood stock the assumption was taken (Tier 1 of IPCC GPG (LULUCF 2006 – Volume 4) that "carbon in dead wood and litter pools in non-forest land are zero, and that carbon in dead organic matter pools increases linearly to the value of mature forests over a specified time period (default = 20 years)".

The EF used for dead wood stock are those described in Figure 1-12 and for litter the default values (Table 2.2 IPCC GPP 2006 Chapter 2) of 16 tonnes C/ha for deciduous and 26 tonnes C/ha for coniferous forests were chosen.

6.3 Cropland (4.B)

6.3.1 Category description

In category *4.B Cropland*, the estimation of emissions from cropland remaining cropland, land converted to cropland and liming is carried out. The calculations were made for the individual years from 1990 to 2015. Some management practices (*e.g.* slash and burn, *etc.*) and organic soils do not occur and are prohibited in Luxembourg.

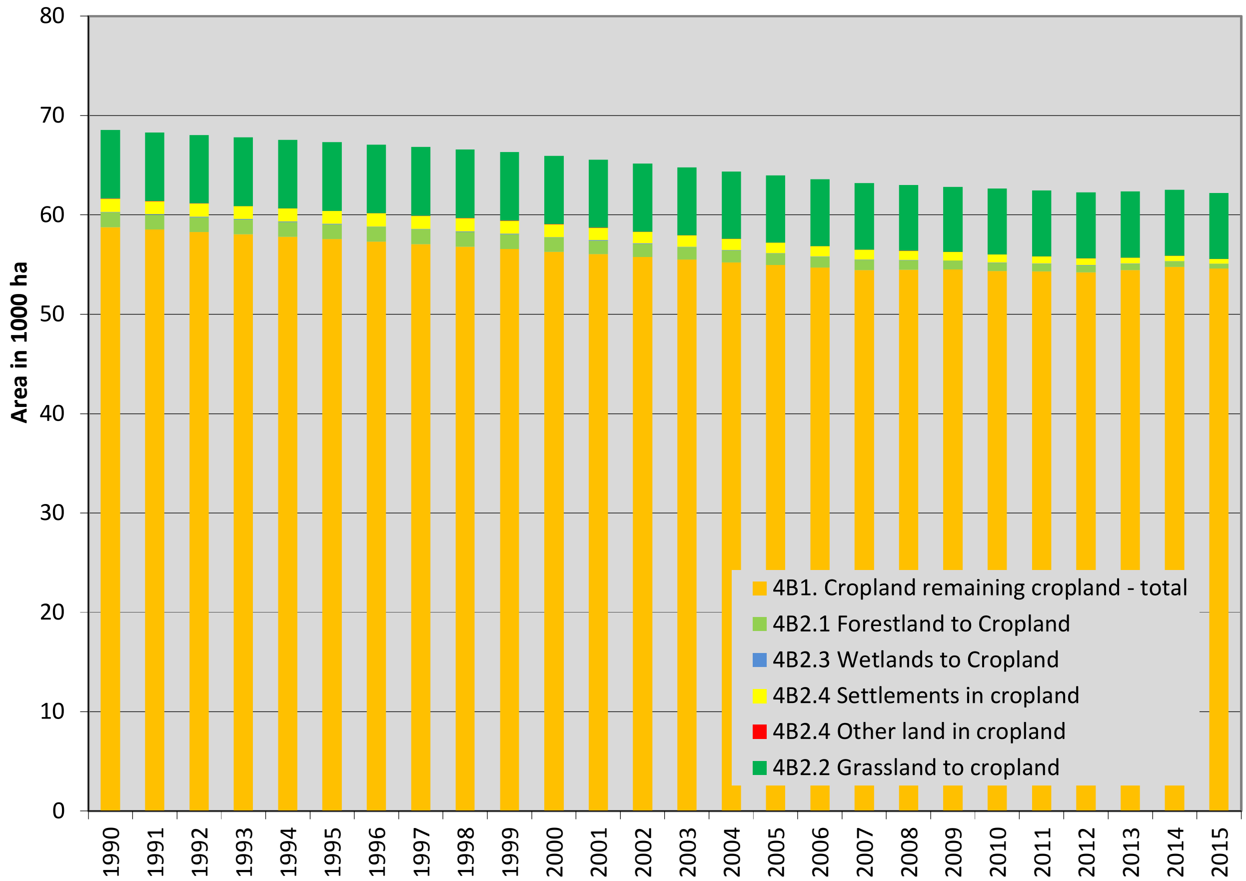
Emissions/Removals were estimated for the sub-categories and related sources/sinks as shown in Table 1-24 .

Table 6-24 – Sources (or sinks) considered for cropland management.

Category/source or sink
4B Cropland - total
4B1 Cropland remaining cropland
- carbon stock change in living biomass of perennial cropland and LUC between annual and perennial copland
4B2 Land converted to cropland
4B2.1Forest land converted to cropland
- carbon stock change in living biomass and dead wood of annual/perennial cropland
4B2.2 Grassland converted to cropland
- carbon stock change in living biomass of annual/perennial cropland
- carbon stock change due to changes in organic matter input to cropland soils
4B2.3 Wetland converted to cropland
4B2.4 Settlement converted to cropland
4B2.5 Other land converted to cropland

In 2015, 62 194 ha of Luxembourg were arable land including annual and permanent crops. The land use changes are derived from land transition matrix (see section 0). In 2015, the land use change area to cropland was 362 ha. The land use changes for a 20 year conversion period are shown in Figure 1-13 .

Figure 6-13 – Trend of cropland and LUC to cropland (20 year conversion period) from 1990-2015



The annual emissions from 1990-2015 range between 79.9 Gg CO_2 equivalent and 42.5 Gg CO_2 equivalent respectively (Table 1-25). The source is mainly caused by soil C stock changes of land use change areas, particularly by grassland converted to cropland.

Table 6-25 – CO_2 removals/emissions from IPCC category 4B – Cropland from 1990-2015

Year	4B - Cropland *Greenhouse gas emissions/removals (Gg CO_2 e)* 4B Total Cropland	4B1 CL remaining CL	4B2 Land -> CL	4B2.1 FL -> CL	4B2.2 GL -> CL	4B2.3 WL -> CL	4B2.4 Settlement -> CL	4B2.5 OL -> CL	N_2O (in CO_2 eq)
1990	*78.88*	*- 1.28*	*80.16*	*47.12*	*36.15*	*- 0.75*	*-7.78*	*-0.24*	*5.66*
1991	*78.88*	*- 1.28*	*80.16*	*47.12*	*36.15*	*- 0.75*	*-7.78*	*-0.24*	*5.66*
1992	*78.88*	*- 1.28*	*80.16*	*47.12*	*36.15*	*- 0.75*	*-7.78*	*-0.24*	*5.66*
1993	*78.88*	*- 1.28*	*80.16*	*47.12*	*36.15*	*- 0.75*	*-7.78*	*-0.24*	*5.66*
1994	*78.88*	*- 1.28*	*80.16*	*47.12*	*36.15*	*- 0.75*	*-7.78*	*-0.24*	*5.66*
1995	*78.88*	*- 1.28*	*80.16*	*47.12*	*36.15*	*- 0.75*	*-7.78*	*-0.24*	*5.66*
1996	*78.88*	*- 1.28*	*80.16*	*47.12*	*36.15*	*- 0.75*	*-7.78*	*-0.24*	*5.66*
1997	*78.88*	*- 1.28*	*80.16*	*47.12*	*36.15*	*- 0.75*	*-7.78*	*-0.24*	*5.66*
1998	*78.88*	*- 1.28*	*80.16*	*47.12*	*36.15*	*- 0.75*	*-7.78*	*-0.24*	*5.66*
1999	*78.88*	*- 1.28*	*80.16*	*47.12*	*36.15*	*- 0.75*	*-7.78*	*-0.24*	*5.66*
2000	*53.67*	*3.42*	*50.24*	*17.94*	*35.48*	*- 0.68*	*-7.87*	*-0.22*	*5.59*
2001	*53.27*	*3.26*	*50.01*	*17.60*	*35.36*	*- 0.65*	*-7.62*	*-0.20*	*5.53*
2002	*52.88*	*3.09*	*49.79*	*17.25*	*35.25*	*- 0.62*	*-7.36*	*-0.19*	*5.47*
2003	*52.49*	*2.93*	*49.56*	*16.90*	*35.13*	*- 0.59*	*-7.11*	*-0.18*	*5.40*
2004	*52.10*	*2.76*	*49.33*	*16.56*	*35.02*	*- 0.56*	*-6.85*	*-0.17*	*5.34*
2005	*51.70*	*2.60*	*49.11*	*16.21*	*34.90*	*- 0.53*	*-6.60*	*-0.16*	*5.28*
2006	*51.31*	*2.43*	*48.88*	*15.86*	*34.79*	*- 0.50*	*-6.34*	*-0.15*	*5.21*
2007	*50.92*	*2.27*	*48.65*	*15.52*	*34.67*	*- 0.47*	*-6.09*	*-0.14*	*5.15*
2008	*43.45*	*2.89*	*40.56*	*8.78*	*33.11*	*- 0.42*	*-5.82*	*-0.12*	*5.04*
2009	*42.84*	*2.71*	*40.13*	*8.37*	*32.75*	*- 0.39*	*-5.41*	*-0.11*	*4.93*
2010	*43.90*	*2.53*	*41.38*	*7.97*	*33.95*	*- 0.35*	*-5.01*	*-0.10*	*4.92*
2011	*43.28*	*2.35*	*40.93*	*7.56*	*33.52*	*- 0.32*	*-4.60*	*-0.09*	*4.86*
2012	*43.59*	*2.17*	*41.42*	*7.15*	*34.00*	*- 0.28*	*-4.20*	*-0.08*	*4.83*
2013	*42.89*	*1.99*	*40.90*	*6.75*	*33.51*	*- 0.25*	*-3.79*	*-0.07*	*4.75*
2014	*42.38*	*1.81*	*40.58*	*6.34*	*33.23*	*- 0.21*	*-3.39*	*-0.06*	*4.66*
2015	*42.50*	*1.63*	*40.87*	*5.94*	*33.53*	*- 0.18*	*-2.98*	*-0.05*	*4.60*
Trend 1990-2015	*-46.13%*	*-226.89%*	*-49.02%*	*-87.40%*	*-7.26%*	*-76.53%*	*-61.66%*	*-80.89%*	*-18.60%*
Trend 2013-2015	*-0.91%*	*-18.13%*	*-0.07%*	*-12.03%*	*0.07%*	*-28.66%*	*-21.36%*	*-33.33%*	*-3.04%*

6.3.2 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation

As described in section 1.1.3.4 an exception to the use of the OBS land use maps was made for LUC areas between cropland and grassland. The LUC areas grassland to cropland respectively cropland to grassland going beyond 269 ha according to OBS were allocated to the category "cropland remaining cropland" for the years 1990-2008. For the years following 2008 data extracted from the LPIS was used to determine land use changes between grassland and cropland.

6.3.3 Land-use definitions and the classification systems used and their correspondence to the LULUCF categories

The LU89, LU99, LU07 and LU12 land use maps are the main data providers for the greenhouse gas reporting of IPCC category cropland, with the exception that for LUC between cropland and grassland, the land transitions matrix needed to be adapted due to special national circumstances as explained in the previous section and in section 1.1.3.3. The selected parameters defining annual and perennial cropland are:

Land Use Class	Definition
Annual Cropland	Includes agro-forestry systems where tree cover falls below the level used in the forest categories (IPCC GPG definition) with the following specifications: land on which different crops are grown in a yearly changed rhythm including artificial meadows (not permanent) including land temporarily set aside
Permanent Cropland	Includes agro-forestry systems where tree cover falls below the level used in the forest categories (IPCC GPG definition) with the following specifications: land on which different crops are grown in a permanent manner, *i.e.* not changing in a yearly rhythm

6.3.4 Methodological issues

6.3.4.1 Cropland remaining Cropland (4B1)

6.3.4.1.1 Change of carbon stock of annual cropland

a) Changes of carbon stock in biomass of annual cropland remaining annual cropland:

As the biomass of annual crops is harvested every year, there is no change in carbon stock in biomass.

b) Changes of carbon stock in biomass of perennial cropland converted to annual cropland:

For the calculation of annual change in carbon stocks of living biomass of land converted to cropland the IPCC GPG 2006 LULUCF Tier 1 method equation 2.15 and 2.16 was applied:

$$\textit{Annual change in carbon stock in biomass} = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L$$

$$\Delta C_{CONVERSION} = \sum_i \{(B_{AFTER_i} - B_{BEFORE_i}) \cdot \Delta A_{TO\_OTHERS_i}\} \cdot CF$$

where :

ΔC_G = annual change in carbon stocks in biomass due to growth on land converted to another land-use category (default value for annual crops carbon accumulation rate is 5 t C $ha^{-1}yr^{-1}$).

$B_{AFTER(i)}$ = stocks on land type i immediately after conversion, tonnes d.m. ha^{-1} (default value = 0).

$B_{BEFORE(i)}$ = stocks on land type i before conversion, tonnes d.m. ha^{-1} (value for carbon stock of woody biomass before conversion is 6.4 t C ha^{-1} see section 1.2.4.2.1 and **Table 1-20** as well as **Table 1-21**)).

ΔC_L = annual decrease in biomass carbon stocks due to losses from harvesting, fuel wood gathering and disturbances on land converted to other land-use category, in tonnes C yr^{-1} (default value = 0).

$\Delta T_{TO\_OTHERS(i)}$ = area of land use I converted to another land-use category in a certain year, ha yr^{-1}.

CF = carbon fraction of dry matter, tonne C (tonne d.m.)$^{-1}$.

i = type of land use converted to another land-use category

c) Changes of carbon stock in organic soils:

Organic soils cannot be found in Luxemburg.

d) Changes of carbon stock in mineral soils of annual cropland remaining annual cropland:

Emissions/removals were calculated using country specific values for the soil organic carbon content. The mean organic carbon content of soil per ha in the layer of 0-30 cm depth was determined for the different land uses (annual cropland, perennial cropland, grassland, forest) by using the values of the soil database of ASTA (Administration des Services Techniques de l'Agriculture, Division des Laboratories de Contrôle et d'Essais, Service de Pédologie).

According to expert judgment (see calculation under Decision 529), there were no significant changes in relative stock change factors (tillage factor FMG; land use factor FLU; input factor FI) during the observation period 1990 to 2015 and these factors are set by default equal to 1. Thus there was no change in carbon stocks in annual cropland soils due to management.

e) Changes of carbon stock in mineral soils of perennial cropland converted to annual cropland:

According to the methodology described in 1.2.4.2.2, annual change in carbon stock of mineral soils = $IEF(LUC_j)$ * conversion area, where :

$$IEF(LUC_{perennial\ cropland\ ->\ annual\ cropland}) = -0.462\ t\ C/ha\ *yr$$

IEF(LUCj) = average yearly emission factor for carbon stock change in soil from land use change

6.3.4.1.2 Change of carbon stock of perennial cropland

a) Changes of carbon stock in biomass of perennial cropland remaining perennial cropland:

According to Tier 1 GPG (2006) for perennial cultures, a steady increase in biomass in the first 30 years is assumed. 3.33% of these cultures are removed and cause emissions. For older cultures the annual increase in biomass is assumed to be equal to the losses by harvesting. For calculating the carbon stock change of living biomass on perennial cropland the following formula was used:

*Annual change in carbon stock in biomass = (area of perennial cropland * carbon accumulation rate) – (area of perennial cropland before 30 years * 0.033 * biomass carbon stock at harvest)*

where:

For the carbon accumulation rate the value of 0.21 t C $ha^{-1}yr^{-1}$ was used (stock at harvest - see below - divided by 30 years rotation cycle).

For the above ground biomass carbon stock at harvest the value of 6.4 t C $ha^{-1}yr^{-1}$ (see **Table 1-21**) was used.

b) Changes of carbon stock in biomass of annual cropland converted to perennial cropland:

For the calculation of annual change in carbon stocks of living biomass of land converted to cropland the IPCC GPG 2006 LULUCF Tier 1 method equation 2.15 and 2.16 was applied:

$$\text{Annual change in carbon stock in biomass} = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L$$

$$\Delta C_{CONVERSION} = \sum_i \{(B_{AFTER_i} - B_{BEFORE_i}) \cdot \Delta A_{TO\_OTHERS_i}\} \cdot CF$$

where :

ΔC_G = annual change in carbon stocks in biomass due to growth on land converted to another land-use category (default value for perennial crops carbon accumulation rate is 0.21 t C $ha^{-1}yr^{-1}$ - see section 1.2.4.2.1 and **Table 1-20** as well as **Table 1-21** = accumulation of 6.4 tC/ha over 30 years).

$B_{AFTER(i)}$ = stocks on land type i immediately after conversion, tonnes d.m. ha^{-1} (default value = 0).

$B_{BEFORE(i)}$ = stocks on land type i before conversion, tonnes d.m. ha^{-1} (value for carbon stock of biomass before conversion is 5 t C ha^{-1} see section 1.2.4.2.1 and **Table 1-20**).

ΔC_L = annual decrease in biomass carbon stocks due to losses from harvesting, fuel wood gathering and disturbances on land converted to other land-use category, in tonnes C yr^{-1} (default value = 0).

$\Delta T_{TO\_OTHERS(i)}$ = area of land use I converted to another land-use category in a certain year, ha yr^{-1}.

CF = carbon fraction of dry matter, tonne C (tonne d.m.)$^{-1}$.

i = type of land use converted to another land-use category

c) Changes of carbon stock in mineral soils of annual cropland converted to perennial cropland :

According to the methodology described in 1.2.4.2.2, annual change in carbon stock of mineral soils = IEF(LUC_j) * conversion area, where :

$$IEF(LUC_{\text{annual cropland -> perennial cropland}}) = +0.462\ t\ C/ha\ {}^*yr$$

IEF(LUCj) = average yearly emission factor for carbon stock change in soil from land use change

6.3.4.2 Land Use Changes to Cropland (4B2)

6.3.4.2.1 Change of carbon stock of land converted to annual cropland

The method follows the IPCC GPG with a transition period of 20 years for LUC areas and related estimates for the increases and decreases of biomass and soil C stocks. Growth rates for annual crops (annual cropland, grassland) are accounted only once in the year of LUC, while growth rates for perennial crops (perennial cropland, forest land) are accounted for the whole period of transition. In line with the IPCC GPG, a linear soil C stock change due to the LUCs between the average soil C stocks across 20 years was estimated.

a) Changes of carbon stock in biomass of land converted to annual cropland:

For the calculation of annual change in carbon stocks of living biomass of land converted to cropland the IPCC GPG 2006 LULUCF Tier 1 method equation 2.15 and 2.16 was applied:

$$\textit{Annual change in carbon stock in biomass} = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L$$

$$\Delta C_{CONVERSION} = \sum_i \left\{ \left(B_{AFTER_i} - B_{BEFORE_i} \right) \cdot \Delta A_{TO\_OTHERS_i} \right\} \cdot CF$$

where :

ΔC_G = annual change in carbon stocks in biomass due to growth on land converted to another land-use category (default value for annual crops carbon accumulation rate is 5 t C $ha^{-1}yr^{-1}$).

$B_{AFTER(i)}$ = stocks on land type i immediately after conversion, tonnes d.m. ha^{-1} (default value = 0).

$B_{BEFORE(i)}$ = stocks on land type i before conversion, tonnes d.m. ha^{-1} (value for carbon stock before conversion is 6.4 t C ha^{-1} for perennial cropland, 119.7 t C ha^{-1} for forestland, 6.3 t C ha^{-1} for grassland, 4.3 t C ha^{-1} for settlements and 0.0 t C ha^{-1} for wetland and other land - see section 1.2.4.2.1 and **Table 1-20**).

ΔC_L = annual decrease in biomass carbon stocks due to losses from harvesting, fuel wood gathering and disturbances on land converted to other land-use category, in tonnes C yr^{-1} (default value = 0).

$\Delta T_{TO\_OTHERS(i)}$ = area of land use I converted to another land-use category in a certain year, ha yr^{-1}.

CF = carbon fraction of dry matter, tonne C (tonne d.m.)$^{-1}$.

b) Changes of carbon stock in dead wood and litter of land converted to cropland:

For the calculation of annual change in carbon stocks of dead wood and litter of land converted to cropland equation 2.23 from the GPG 2006 is used:

$$\Delta D_{DOM} = \frac{(C_n - C_o) \cdot A_{on}}{T_{on}}$$

where :

ΔC_{DOM} = annual change in carbon stocks in dead wood or litter (tonnes C yr^{-1})

C_o = dead wood/litter stock, under the old land-use category, tonnes C ha^{-1} (value dead wood in forest = 5,1 t C/ha*yr (average between forest inventory from 2000 and 2010) & default value for litter in forest = 19,2 t C/ha*yr (weighted average between default values of Table 2.2 of GPG 2006).

C_n = dead wood/litter stock, under the new land-use category, tonnes C ha^{-1} (default value = 0 for all land-use categories but forest)

A_{on} = area undergoing conversion from old to new land-use category, ha

T_{on} = time period of the transition from old to new land-use category, yr. The Tier 1 default is 20 years for carbon stock increases and 1 year for carbon losses.

d) Changes of carbon stock in mineral soils of land converted to annual cropland:

According to the methodology described in 1.2.4.2.2, annual change in carbon stock of mineral soils = $IEF(LUC_j)$ * conversion area, where :

$$IEF(LUC_{forestland \rightarrow annual\ cropland}) = -1.237\ t\ C/\ ha\ {*}yr$$

$$IEF(LUC_{grassland \rightarrow annual\ cropland}) = -1.308\ t\ C/\ ha\ {*}yr$$

$$IEF(LUC_{wetland \rightarrow annual\ cropland}) = +3.770\ t\ C/\ ha\ {*}yr$$

$$IEF(LUC_{settlements \rightarrow annual\ cropland}) = +1.609\ t\ C/\ ha\ {*}yr$$

$$IEF(LUC_{other\ land \rightarrow annual\ cropland}) = +3.770\ t\ C/\ ha\ {*}yr$$

IEF(LUCj) = average yearly emission factor for carbon stock change in soil from land use change j (eg forestland in cropland)

6.3.4.2.2 Change of carbon stock of land converted to perennial cropland

The method follows the IPCC GPG with a transition period of 20 years for LUC areas and related estimates for the increases and decreases of biomass and soil C stocks. Growth rates for annual crops (annual cropland, grassland) are accounted only once in the year of LUC, while growth rates for perennial crops (perennial cropland, forest land) are accounted for the whole period of transition. In line with the IPCC GPG, a linear soil C stock change due to the LUCs between the average soil C stocks across 20 years was estimated.

a) Changes of carbon stock in biomass land converted to perennial cropland:

For the calculation of annual change in carbon stocks of living biomass of grassland converted to perennial cropland the IPCC GPG 2006 LULUCF Tier 1 method equation 2.15 and 2.16 was applied:

$$\text{Annual change in carbon stock in biomass} = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L$$

$$\Delta C_{CONVERSION} = \sum_i \{(B_{AFTER_i} - B_{BEFORE_i}) \cdot \Delta A_{TO\_OTHERS_i}\} \cdot CF$$

where :

ΔC_G = annual change in carbon stocks in biomass due to growth on land converted to another land-use category (default value for perennial crops carbon accumulation rate is 0.21 t C $ha^{-1}yr^{-1}$).

$B_{AFTER(i)}$ = stocks on land type i immediately after conversion, tonnes d.m. ha^{-1} (default value = 0).

$B_{BEFORE(i)}$ = stocks on land type i before conversion, tonnes d.m. ha^{-1} (value for carbon stock before conversion is 5.0 t C ha^{-1} for annual cropland, 119.7 t C ha^{-1} for forestland, 6.3 t C ha^{-1} for grassland, 4.3 t C ha^{-1} for settlements and 0.0 t C ha^{-1} for wetland and other land - see section 1.2.4.2.1 and **Table 1-20**).

ΔC_L = annual decrease in biomass carbon stocks due to losses from harvesting, fuel wood gathering and disturbances on land converted to other land-use category, in tonnes C yr^{-1} (default value = 0).

$\Delta T_{TO\_OTHERS(i)}$ = area of land use I converted to another land-use category in a certain year, ha yr^{-1}.

CF = carbon fraction of dry matter, tonne C (tonne d.m.)$^{-1}$.

i = type of land use converted to another land-use category

b) Changes of carbon stock in dead wood and litter of land converted to cropland:

For the calculation of annual change in carbon stocks of dead wood and litter of land converted to cropland equation 2.23 from the GPG 2006 is used:

$$\Delta D_{DOM} = \frac{(C_n - C_o) \cdot A_{on}}{T_{on}}$$

where :

ΔC_{DOM} = annual change in carbon stocks in dead wood or litter (tonnes C yr^{-1})

C_o = dead wood/litter stock, under the old land-use category, tonnes C ha^{-1} (value dead wood in forest = 5.1 t C/ha*yr (average between forest inventory from 2000 and 2010) & default value for litter in forest = 19.2 t C/ha*yr (weighted average between default values of Table 2.2 of GPG 2006).

C_n = dead wood/litter stock, under the new land-use category, tonnes C ha^{-1} (default value = 0 for all land-use categories but forest)

A_{on} = area undergoing conversion from old to new land-use category, ha

T_{on} = time period of the transition from old to new land-use category, yr. The Tier 1 default is 20 years for carbon stock increases and 1 year for carbon losses.

c) Changes of carbon stock in mineral soils of land converted to perennial cropland:

According to the methodology described in 1.2.4.2.2, annual change in carbon stock of mineral soils = IEF(LUC_j) * conversion area, where :

$$IEF(LUC_{forestland \rightarrow perennial\ cropland}) = -1.237\ t\ C/ha*yr$$

$$IEF(LUC_{grassland \rightarrow perennial\ cropland}) = -1.517\ t\ C/ha*yr$$

$$IEF(LUC_{wetland \rightarrow perennial\ cropland}) = +5.079\ t\ C/ha*yr$$

$$IEF(LUC_{settlements \rightarrow perennial\ cropland}) = +2.917\ t\ C/ha*yr$$

$$IEF(LUC_{other\ land \rightarrow perennial\ cropland}) = +5.079\ t\ C/ha*yr$$

IEF(LUCj) = average yearly emission factor for carbon stock change in soil from land use change j (eg forestland in cropland)

6.3.4.2.3 N_2O emissions in soils of land converted to cropland

The annual release of direct N_2O emissions due to the conversion of land to cropland was calculated with IPCC default value (Tier 1) using equation 11.2 and 11.8 of the IPCC GPG (2006):

$$N_2O_{Direct} - N = F_{SOM} \cdot EF_1$$

$$F_{SOM} = \sum_{LU} \left[\left(\Delta C_{Mineral,LUC} \cdot \frac{1}{R} \right) \cdot 1000 \right]$$

where:

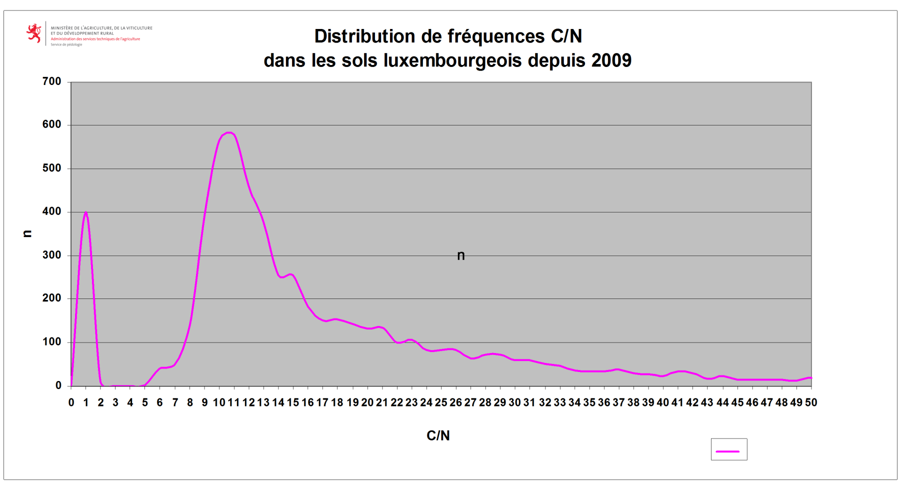
EF_1=emission factor for N mineralised as a result of loss of soil carbon (default value = 0.01)

F_{SOM}= the net annual amount of N mineralised in mineral soils as a result of loss of soil carbon through change in land use or management, kg N

$\Delta C_{Mineral,LU}$ = average annual loss of soil carbon for each land-use type (LU), tonnes C

R = C/N ratio = ratio by mass of C to N in the soil organic matter = 12. The country-specific C/N was derived from soil analysis done in 2009 (ARR 2011, §107), where C and N content was determined. The distribution curve of C/N ratio (as shown in Figure 1-14) shows a mean C/N ratio of approximately 12. Nevertheless it is important to highlight that the C/N ratio on mineral soils does not have the same significance compared to organic soils in forests. This is due the presence of nitrogen in the form of ammonium fixed in clay minerals. In this case the C/N ratio is however used to determine the potential of mineralisation of nitrogen contained in the organic matter. Separate soil analysis of C/N fraction does not exist for the different soil uses (forestland, grassland etc). According to expert judgement (ASTA) the best available value at this moment in time remains 12.

Figure 6-14 - Frequency distribution of C/N ratio in Luxembourg's soils since 2009



Source: ASTA

The annual release of indirect N_2O emissions due to the conversion of land to cropland was calculated with IPCC default value (Tier 1) using equation 11.10 of the IPCC GPG (2006):

$$N_2O_{(L)} - N = F_{SOM} \cdot Frac_{LEACH-(H)} \cdot EF_5$$

where:

$N_2O_{(L)}$-N=annual amount of N_2O-N produced from leaching and runoff of N additions to managed soils in regions where leaching/runoff occurs, kgN_2O-Nyr^{-1}

F_{SOM}= the net annual amount of N mineralised in mineral soils as a result of loss of soil carbon through change in land use or management, kg N

EF_5=emission factor for N_2O emissions from N leaching result of loss of soil carbon (default value = 0.0075)

$Frac_{LEACH-(H)}$=fraction of all N added to/mineralised in managed soils in regions where leaching/runoff occurs that is lost through leaching and runoff, kgN (kg of N additions)$^{-1}$ (default value = 0.30)

6.4 Grassland (4.C)

6.4.1 Category description

In this category emissions/removals from grassland management (grassland remaining grassland and land converted to grassland) are considered.

Some management practices (*e.g.* slash and burn *etc.*) and organic soils do not occur in Luxembourg. Dead wood and litter are considered in forestland converted to grass land areas but not for the remaining land categories converted to grassland.

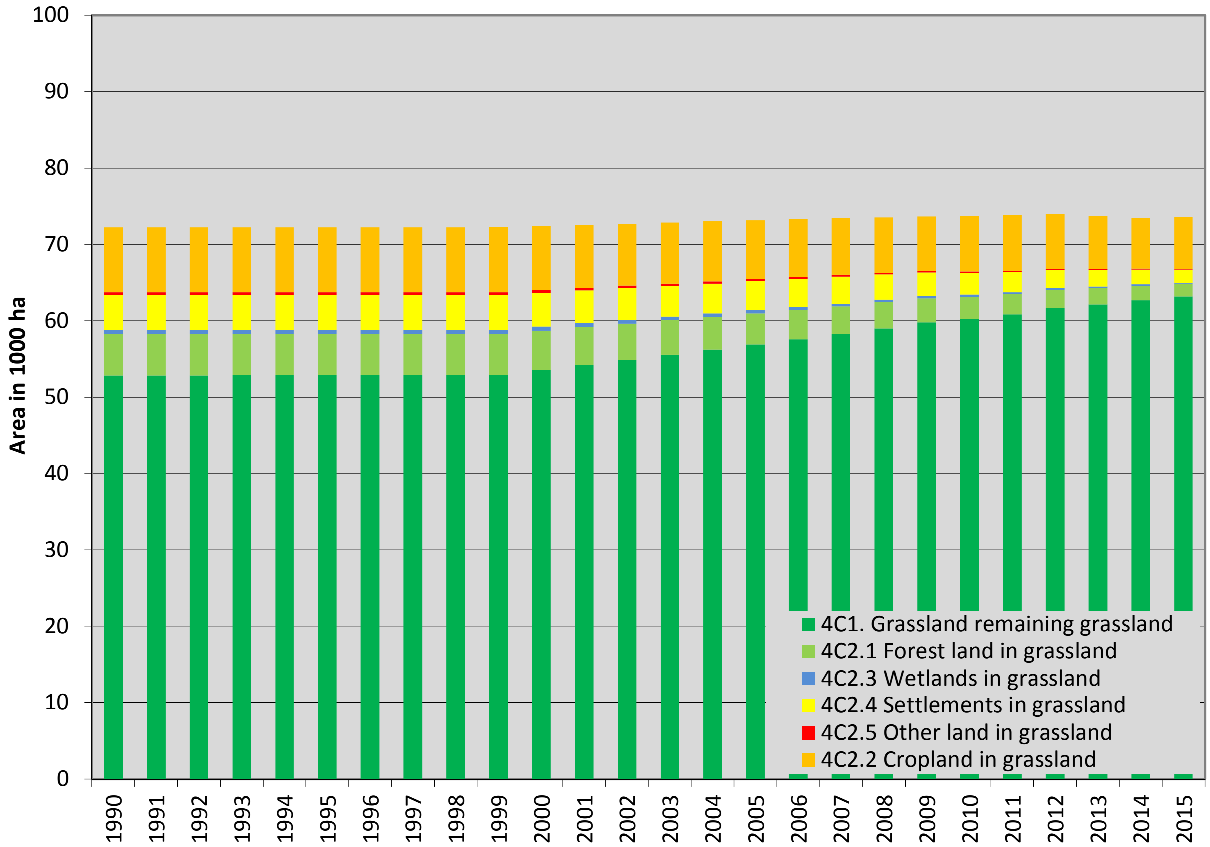
Emissions/Removals were estimated for the following IPCC sub-categories and their related sources/sinks (Table 1-26).

Table 6-26 – Sources (or sinks) considered for grassland management.

Category/source or sink
4C Grassland - total
4C1 Grassland remaining grassland
- carbon stock change due to changes in organic matter input to grassland soils
4C2Land converted to grassland
4C2.1Forest land converted to grassland
4C2.2 Cropland converted to grassland
- carbon stock change in living biomass of grassland
- carbon stock change due to changes in organic matter input (harvest residues) to grassland soils
4C2.3 Wetland converted to grassland
4C2.4 Settlement converted to grassland
4C2.5 Other land converted to grassland

In 2015, 73 293 ha of Luxembourg were grassland (Figure 1-15). Total grassland includes one cut meadows; two and more cut meadows, cultivated pastures, litter meadows, rough pastures and pastures and abandoned grassland.

Figure 6-15 – Trend of grassland and LUC to grassland (20 year conversion period) from 1990-2015



The annual emissions of grassland in Luxembourg amounted to 32.90 Gg CO_2 in 1990 and − 46.64 Gg CO_2 in 2015 (Table 1-27). The source is mainly caused by soil C stock changes in land use change areas, particularly by forestland converted to grassland.

Table 6-27 – CO_2 removals/emissions from IPCC category 5C – Grassland from 1990-2015

4C - Grassland

Greenhouse gas emissions/removals (Gg CO_2 e)

Year	4C Total Grassland	4C1 GL remaining GL	4C2 Land -> GL	4C2.1 FL -> GL	4C2.2 CL -> GL	4C2.3 WL -> GL	4C2.4 Settlement -> GL	4C2.5 OL -> GL	N_2O (in CO_2 eq)
1990	32.90	NO	32.90	145.13	- 44.56	- 11.26	-50.18	-7.45	1.22
1991	32.90	NO	32.90	145.13	- 44.56	- 11.26	-50.18	-7.45	1.22
1992	32.90	NO	32.90	145.13	- 44.56	- 11.26	-50.18	-7.45	1.22
1993	32.90	NO	32.90	145.13	- 44.56	- 11.26	-50.18	-7.45	1.22
1994	32.90	NO	32.90	145.13	- 44.56	- 11.26	-50.18	-7.45	1.22
1995	32.90	NO	32.90	145.13	- 44.56	- 11.26	-50.18	-7.45	1.22
1996	32.90	NO	32.90	145.13	- 44.56	- 11.26	-50.18	-7.45	1.22
1997	32.90	NO	32.90	145.13	- 44.56	- 11.26	-50.18	-7.45	1.22
1998	32.90	NO	32.90	145.13	- 44.56	- 11.26	-50.18	-7.45	1.22
1999	32.90	NO	32.90	145.13	- 44.56	- 11.26	-50.18	-7.45	1.22
2000	- 72.27	NO	- 72.27	35.22	- 43.84	- 10.24	-47.92	-6.67	1.17
2001	- 69.80	NO	- 69.80	34.84	- 43.09	- 9.79	-46.58	-6.32	1.12
2002	- 67.34	NO	- 67.34	34.47	- 42.34	- 9.33	-45.24	-5.97	1.08
2003	- 64.88	NO	- 64.88	34.09	- 41.59	- 8.88	-43.90	-5.62	1.03
2004	- 62.41	NO	- 62.41	33.71	- 40.84	- 8.43	-42.56	-5.27	0.98
2005	- 59.95	NO	- 59.95	33.33	- 40.09	- 7.97	-41.22	-4.92	0.93
2006	- 57.49	NO	- 57.49	32.95	- 39.34	- 7.52	-39.89	-4.57	0.88
2007	- 55.02	NO	- 55.02	32.57	- 38.59	- 7.06	-38.55	-4.22	0.83
2008	- 67.29	NO	- 67.29	15.39	- 37.73	- 6.44	-35.41	-3.87	0.77
2009	- 63.63	NO	- 63.63	14.96	- 36.86	- 5.91	-33.01	-3.52	0.71
2010	- 63.16	NO	- 63.16	14.52	- 39.18	- 5.39	-30.61	-3.17	0.66
2011	- 59.66	NO	- 59.66	14.08	- 38.47	- 4.86	-28.20	-2.81	0.60
2012	- 54.87	NO	- 54.87	13.65	- 36.47	- 4.33	-25.80	-2.46	0.54
2013	- 50.84	NO	- 50.84	13.21	- 35.23	- 3.80	-23.40	-2.11	0.49
2014	- 45.92	NO	- 45.92	12.77	- 33.09	- 3.27	-21.00	-1.76	0.43
2015	- 46.64	NO	- 46.64	12.34	- 36.60	- 2.74	-18.59	-1.41	0.37
Trend 1990-2015	-241.74%	NA	-241.74%	-91.50%	-17.86%	-75.64%	-62.95%	-81.05%	-69.48%
Trend 2013-2015	-8.27%	NA	-8.27%	-6.61%	3.89%	-27.82%	-20.54%	-33.19%	-23.36%

6.4.2 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation

An exception to the use of the OBS land use maps has been made for LUC areas between cropland and grassland (see section 0). The LUC areas grassland to cropland respectively cropland to grassland going beyond 269 ha (or LPIS data after 2009) according to OBS were allocated to the category "cropland remaining cropland".

6.4.3 Land-use definitions and the classification systems used and their correspondence to the LULUCF categories

The LU89, LU99, LU07 and LU12 land use maps are the main data providers for the greenhouse gas reporting of IPCC category grassland, with the selected parameters defining grassland:

Land Use Class	Definition
Grassland	All grassland that is not considered as cropland including systems with vegetation or tree cover below the density used in the forest category. This includes all grassland from wild lands, recreational areas as well as agricultural systems. (IPCC GPG definition).

6.4.4 Methodological issues

6.4.4.1 Grassland remaining Grassland (4C1)

6.4.4.1.1 Carbon stock change of grassland

a) Changes in carbon stock in biomass of grassland remaining grassland:
As the biomass of grassland is harvested every year, there is no long term carbon storage in biomass of grassland remaining grassland.

b) Changes in carbon stock in mineral soils of grassland remaining grassland:
As for cropland, according to expert judgment, there was no change in relative stock change factors (tillage factor FMG; land use factor FLU; input factor FI) during the observation period 1990 to 2015 and these factors are set by default equal to 1. Thus, there was no change in carbon stocks in grassland soils due to management.

Consequently, there are neither emissions nor removals in IPPC Sub-category *5C1 - Grassland remaining Grassland*, due to the fact that the biomass of grassland remaining grassland is harvested every year, and that there is no change in carbon stocks in grassland soils due to management (expert judgement).

6.4.4.2 Land Use Changes to Grassland (4C2)

The method follows the IPCC GPG with a transition period of 20 years for LUC areas and related estimates for the increases and decreases of biomass and soil C stocks. Growth rates for annual crops (annual cropland, grassland) are accounted only once in the year of LUC, while growth rates for perennial crops (perennial cropland, forest land) are accounted for the whole period of transition. In line with the IPCC GPG, a linear soil C stock change due to the LUCs between the average soil C stocks across 20 years was estimated.

a) Changes in carbon stock in biomass of land converted to grassland:

For the calculation of annual change in carbon stocks of living biomass of land converted to grassland the IPCC GPG 2006 LULUCF Tier 1 method equation 2.15 and 2.16 was applied:

$$\textit{Annual change in carbon stock in biomass} = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L$$

$$\Delta C_{CONVERSION} = \sum_i \{(B_{AFTER_i} - B_{BEFORE_i}) \cdot \Delta A_{TO\_OTHERS_i}\} \cdot CF$$

where:

ΔC_G = annual change in carbon stocks in biomass due to growth on land converted to another land-use category (default value for grassland carbon accumulation rate is 6.3 t C $ha^{-1}yr^{-1}$).

$B_{AFTER(i)}$ = stocks on land type i immediately after conversion, tonnes d.m. ha^{-1} (default value = 0).

$B_{BEFORE(i)}$ = stocks on land type i before conversion, tonnes d.m. ha^{-1} (value for carbon stock before conversion is 6.4 t C ha^{-1} for perennial cropland, 119.7 t C ha^{-1} for forestland, 5.0 t C ha^{-1} for annual cropland, 4.3 t C ha^{-1} for settlements and 0.0 t C ha^{-1} for wetland and other land- see section 1.2.4.2.1 and **Table 1-20**).

ΔC_L = annual decrease in biomass carbon stocks due to losses from harvesting, fuel wood gathering and disturbances on land converted to other land-use category, in tonnes C yr^{-1} (default value = 0).

$\Delta T_{TO\_OTHERS(i)}$ = area of land use I converted to another land-use category in a certain year, ha yr^{-1}.

CF = carbon fraction of dry matter, tonne C (tonne d.m.)$^{-1}$.

i = type of land use converted to another land-use category

b) Changes of carbon stock in dead wood and litter of land converted to grassland:

For the calculation of annual change in carbon stocks of dead wood and litter of land converted to grassland equation 2.23 from the GPG 2006 is used:

$$\Delta D_{DOM} = \frac{(C_n - C_o) \cdot A_{on}}{T_{on}}$$

where :

ΔC_{DOM} = annual change in carbon stocks in dead wood or litter (tonnes C yr^{-1})

C_o = dead wood/litter stock, under the old land-use category, tonnes C ha^{-1} (value dead wood in forest = 5.1 t C/ha*yr (average between forest inventory from 2000 and 2010) & default value for litter in forest = 19.2 t C/ha*yr (weighted average between default values of Table 2.2 of GPG 2006).

C_n = dead wood/litter stock, under the new land-use category, tonnes C ha^{-1} (default value = 0 for all land-use categories but forest)

A_{on} = area undergoing conversion from old to new land-use category, ha

T_{on} = time period of the transition from old to new land-use category, yr. The Tier 1 default is 20 years for carbon stock increases and 1 year for carbon losses

c) Changes in carbon stock in mineral soil of land converted to grassland:

According to the methodology described in 1.2.4.2.2, annual change in carbon stock of mineral soils = IEF(LUC_j) * conversion area, where:

$$IEF(LUC_{forestland \rightarrow grassland}) = -0.476\ t\ C/ha\ *yr$$

$$IEF(LUC_{annual\ cropland \rightarrow grassland}) = +1.308\ t\ C/ha\ *yr$$

$$IEF(LUC_{perennial\ cropland \rightarrow grassland}) = +1.517\ t\ C/ha\ *yr$$

$$IEF(LUC_{wetland \rightarrow grassland}) = +5.079\ t\ C/ha\ *yr$$

$$IEF(LUC_{settlements \rightarrow grassland}) = +2.917\ t\ C/ha\ *yr$$

$$IEF(LUC_{other\ land \rightarrow grassland}) = +5.079\ t\ C/ha\ *yr$$

IEF(LUCj) = average yearly emission factor for carbon stock change in soil from land use change

6.4.4.2.1 N_2O emissions in soils of land converted to grassland

The annual release of direct N_2O emissions due to the conversion of land to grassland was calculated with IPCC default value (Tier 1) using equation 11.2 and 11.8 of the IPCC GPG (2006):

$$N_2O_{Direct} - N = F_{SOM} \cdot EF_1$$

$$F_{SOM} = \sum_{LU}\left[\left(\Delta C_{Mineral,LUC} \cdot \frac{1}{R}\right) \cdot 1000\right]$$

where:

EF_1=emission factor for N mineralised as a result of loss of soil carbon (default value = 0.01)

F_{SOM}= the net annual amount of N mineralised in mineral soils as a result of loss of soil carbon through change in land use or management, kg N

$\Delta C_{Mineral,LU}$ = average annual loss of soil carbon for each land-use type (LU), tonnes C

R = C/N ratio = ratio by mass of C to N in the soil organic matter = 12.

The annual release of indirect N_2O emissions due to the conversion of land to cropland was calculated with IPCC default value (Tier 1) using equation 11.10 of the IPCC GPG (2006):

$$N_2O_{(L)} - N = F_{SOM} \cdot Frac_{LEACH-(H)} \cdot EF_5$$

where:

$N2O_{(L)}$-N=annual amount of N_2O-N produced from leaching and runoff of N additions to managed soils in regions where leaching/runoff occurs, $kgN_2O\text{-}Nyr^{-1}$

F_{SOM}= the net annual amount of N mineralised in mineral soils as a result of loss of soil carbon through change in land use or management, kg N

EF_5=emission factor for N_2O emissions from N leaching result of loss of soil carbon (default value = 0.0075)

$Frac_{LEACH-(H)}$=fraction of all N added to/mineralised in managed soils in regions where leaching/runoff occurs that is lost through leaching and runoff, kgN (kg of N additions)$^{-1}$ (default value = 0.30)

6.5 Wetlands (4.D)

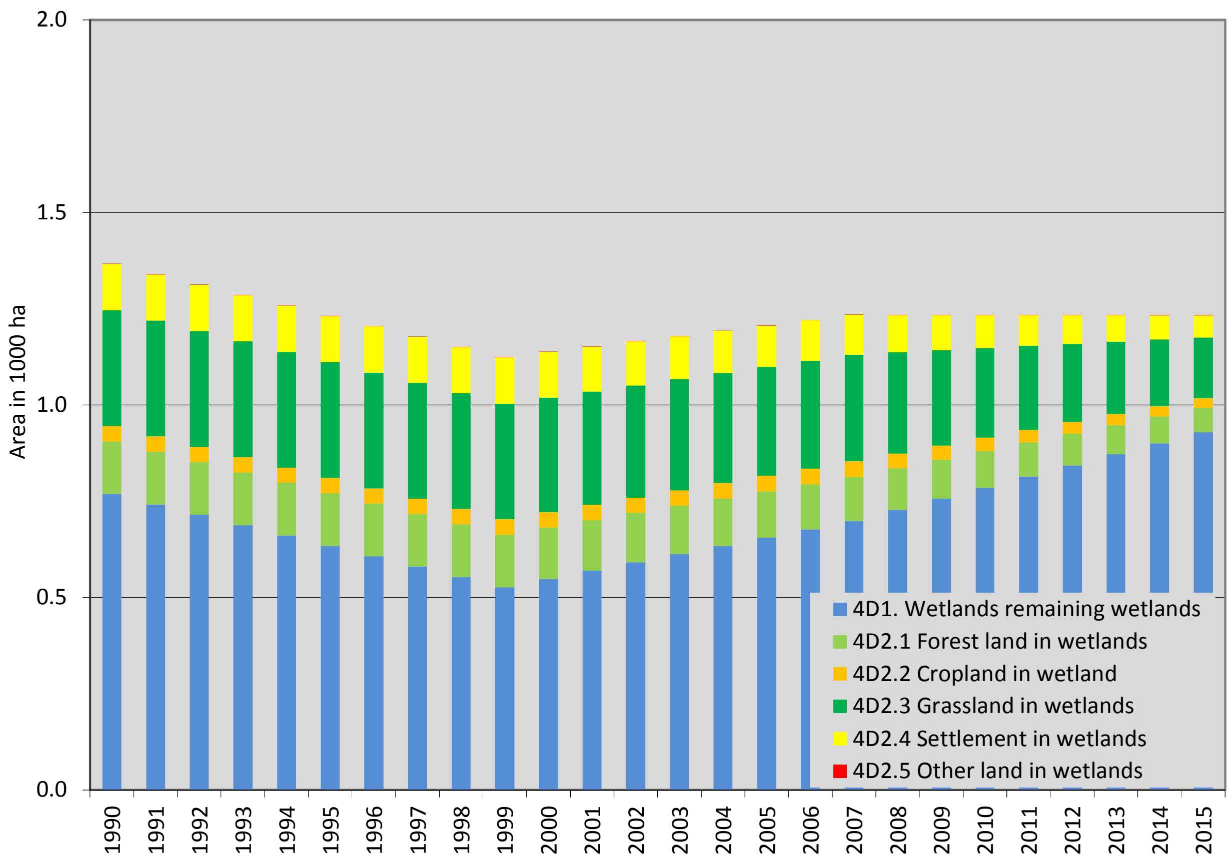
6.5.1 Category description

In this category emissions/removals from land converted to wetland are considered.

Due to the lack of information, it is assumed that the C stock in biomass, dead organic matter and soil of surface waters is zero.

In 2015, 1 233 ha of Luxembourg were wetland (Figure 1-16). Total wetland includes any areas covered by water (rivers, lakes, *etc.*) or saturated by water (marshes, mires, *etc.*). There is no peat land, hence no organic soils in wetlands in Luxembourg.

Figure 6-16 – Trend of wetland and LUC to wetland (20 year conversion period) from 1990-2015



The annual emissions from wetland in Luxembourg amounted to 16.4 Gg CO_2 in 1990 and 6.0 Gg CO_2 in 2015 (Table 1-27). The source is mainly caused by soil C stock changes in land use change areas, particularly by forestland and grassland converted to wetland.

Table 6-28 – CO_2 removals/emissions from IPCC category 4D – Wetland from 1990-2015

Year	4D - Wetland *Greenhouse gas emissions/removals (Gg CO_2 e)* 4D Total Wetland	4D1 WL remaining WL	4D2 Land -> WL	4D2.1 FL -> WL	4D2.2 CL -> WL	4D2.3 GL -> WL	4D2.4 Settlements -> WL	4D2.5 OL -> WL	N_2O (in CO_2 eq)
1990	*16.45*	*NE*	*16.45*	*7.52*	*0.59*	*5.94*	*1.05*	*0.00*	*1.35*
1991	*16.45*	*NE*	*16.45*	*7.52*	*0.59*	*5.94*	*1.05*	*0.00*	*1.35*
1992	*16.45*	*NE*	*16.45*	*7.52*	*0.59*	*5.94*	*1.05*	*0.00*	*1.35*
1993	*16.45*	*NE*	*16.45*	*7.52*	*0.59*	*5.94*	*1.05*	*0.00*	*1.35*
1994	*16.45*	*NE*	*16.45*	*7.52*	*0.59*	*5.94*	*1.05*	*0.00*	*1.35*
1995	*16.45*	*NE*	*16.45*	*7.52*	*0.59*	*5.94*	*1.05*	*0.00*	*1.35*
1996	*16.45*	*NE*	*16.45*	*7.52*	*0.59*	*5.94*	*1.05*	*0.00*	*1.35*
1997	*16.45*	*NE*	*16.45*	*7.52*	*0.59*	*5.94*	*1.05*	*0.00*	*1.35*
1998	*16.45*	*NE*	*16.45*	*7.52*	*0.59*	*5.94*	*1.05*	*0.00*	*1.35*
1999	*16.45*	*NE*	*16.45*	*7.52*	*0.59*	*5.94*	*1.05*	*0.00*	*1.35*
2000	*14.10*	*NE*	*14.10*	*5.35*	*0.59*	*5.82*	*1.00*	*0.00*	*1.33*
2001	*13.93*	*NE*	*13.93*	*5.27*	*0.59*	*5.77*	*0.98*	*0.00*	*1.31*
2002	*13.76*	*NE*	*13.76*	*5.19*	*0.59*	*5.71*	*0.96*	*0.00*	*1.29*
2003	*13.59*	*NE*	*13.59*	*5.11*	*0.59*	*5.66*	*0.95*	*0.00*	*1.27*
2004	*13.42*	*NE*	*13.42*	*5.03*	*0.59*	*5.61*	*0.93*	*0.00*	*1.25*
2005	*13.25*	*NE*	*13.25*	*4.95*	*0.59*	*5.55*	*0.91*	*0.00*	*1.23*
2006	*13.08*	*NE*	*13.08*	*4.87*	*0.60*	*5.50*	*0.89*	*0.00*	*1.22*
2007	*12.91*	*NE*	*12.91*	*4.79*	*0.60*	*5.45*	*0.88*	*0.00*	*1.20*
2008	*9.97*	*NE*	*9.97*	*2.64*	*0.53*	*4.89*	*0.78*	*0.00*	*1.13*
2009	*9.39*	*NE*	*9.39*	*2.48*	*0.51*	*4.61*	*0.73*	*0.00*	*1.06*
2010	*8.82*	*NE*	*8.82*	*2.32*	*0.48*	*4.34*	*0.68*	*0.00*	*1.00*
2011	*8.25*	*NE*	*8.25*	*2.16*	*0.45*	*4.06*	*0.64*	*0.00*	*0.93*
2012	*7.68*	*NE*	*7.68*	*2.01*	*0.43*	*3.78*	*0.59*	*0.00*	*0.87*
2013	*7.10*	*NE*	*7.10*	*1.85*	*0.40*	*3.51*	*0.55*	*0.00*	*0.80*
2014	*6.53*	*NE*	*6.53*	*1.69*	*0.38*	*3.23*	*0.50*	*0.00*	*0.73*
2015	*5.96*	*NE*	*5.96*	*1.53*	*0.35*	*2.95*	*0.46*	*0.00*	*0.67*
Trend 1990-2015	*-63.77%*	*NA*	*-63.77%*	*-79.61%*	*-40.81%*	*-50.30%*	*-56.39%*	*NA*	*NA*
Trend 2013-2015	*-16.11%*	*NA*	*-16.11%*	*-17.05%*	*-13.01%*	*-15.81%*	*-16.53%*	*NA*	*NA*

6.5.2 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation

For a detailed description of the development of the land transition matrix, please refer to section 1.1.3.3.

6.5.3 Land-use definitions and the classification systems used and their correspondence to the LULUCF categories

The LU89, LU99, LU07 and LU12 land use maps are the main data providers for the greenhouse gas reporting of IPCC category wetland. The selected parameters defining wetland are:

Land Use Class	Definition
Wetland	Land that is covered or saturated by water for all or part of the year (*e.g.* peat land) and that does not fall into other categories.
Water	Land that is covered by water for all the year and that does not fall into other categories. This includes reservoirs. (IPCC GPG definition)

6.5.4 Methodological issues

6.5.4.1 Wetlands remaining Wetlands (4D1)

Due to a lack of required data on carbon stock changes, this category has not yet been estimated. Thus, it is assumed that the C stock in biomass, dead organic matter and soil of surface waters is 0. However, it should be noted, that areas next to rivers or lakes which can be flooded, are considered as grassland, as these areas are most often being used as grazingland for animals.

6.5.4.2 Land Use Changes to Wetlands (4D2)

a) Changes in carbon stock in biomass of land converted to grassland:

For the calculation of the annual change in carbon stocks of living biomass in land converted to wetland the following equation IPCC GPG 2006 LULUCF Tier 1 method equation 2.15 and 2.16 was applied:

$$\textit{Annual change in carbon stock in biomass} = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L$$

$$\Delta C_{CONVERSION} = \sum_i \left\{ \left(B_{AFTER_i} - B_{BEFORE_i} \right) \cdot \Delta A_{TO\_OTHERS_i} \right\} \cdot CF$$

where :

ΔC_G = annual change in carbon stocks in biomass due to growth on land converted to another land-use category (default value for carbon accumulation rate is 0.0 t C $ha^{-1}yr^{-1}$).

$B_{AFTER(i)}$ = stocks on land type i immediately after conversion, tonnes d.m. ha^{-1} (default value = 0).

$B_{BEFORE(i)}$ = stocks on land type i before conversion, tonnes d.m. ha^{-1} (value for carbon stock before conversion is 6.4 t C ha^{-1} for perennial cropland, 119.7 t C ha^{-1} for forestland, 6.3 t C ha^{-1} for grassland, 4.3 t C ha^{-1} for settlements, 5.0 t C ha^{-1} for annual cropland and 0.0 t C ha^{-1} other land - see section 1.2.4.2.1 and **Table 1-20**).

ΔC_L = annual decrease in biomass carbon stocks due to losses from harvesting, fuel wood gathering and disturbances on land converted to other land-use category, in tonnes C yr^{-1} (default value = 0).

$\Delta T_{TO\_OTHERS(i)}$ = area of land use I converted to another land-use category in a certain year, ha yr^{-1}.

CF = carbon fraction of dry matter, tonne C (tonne d.m.)$^{-1}$.

b) Changes of carbon stock in dead wood and litter of land converted to wetland:

For the calculation of annual change in carbon stocks of dead wood and litter of land converted to wetland equation 2.23 from the GPG 2006 is used:

$$\Delta D_{DOM} = \frac{(C_n - C_o) \cdot A_{on}}{T_{on}}$$

where :

ΔC_{DOM} = annual change in carbon stocks in dead wood or litter (tonnes C yr^{-1})

C_o = dead wood/litter stock, under the old land-use category, tonnes C ha^{-1} (value dead wood in forest = 5.1 t C/ha*yr (average between forest inventory from 2000 and 2010) & default value for litter in forest = 19.2 t C/ha*yr (weighted average between default values of Table 2.2 of GPG 2006).

C_n = dead wood/litter stock, under the new land-use category, tonnes C ha^{-1} (default value = 0 for all land-use categories but forest)

A_{on} = area undergoing conversion from old to new land-use category, ha

T_{on} = time period of the transition from old to new land-use category, yr. The Tier 1 default is 20 years for carbon stock increases and 1 year for carbon losses

c) Changes in carbon stocks in soil of land converted to wetland

According to the methodology described in 1.2.4.2.2, annual change in carbon stock of mineral soils = IEF(LUC_j) * conversion area, where :

$$IEF(LUC_{forestland\ ->\ wetland}) = -\ 5.554\ t\ C/\ ha\ *yr$$

$$IEF(LUC_{perennial\ cropland\ ->\ wetland}) = -\ 3.778\ t\ C/\ ha\ *yr$$

$$IEF(LUC_{annual\ cropland\ ->\ wetland}) = -3.770\ t\ C/\ ha\ *yr$$

$$IEF(LUC_{grassland\ ->\ wetland}) = -\ 5.079\ t\ C/\ ha\ *yr$$

$$IEF(LUC_{settlements\ ->\ wetland}) = -\ 2.917\ t\ C/\ ha\ *yr$$

$$IEF(LUC_{other\ land\ ->\ wetland}) = 2.162\ t\ C/\ ha\ *yr$$

IEF(LUCj) = average yearly emission factor for carbon stock change in soil from land use change

6.5.4.2.1 N_2O emissions in soils of land converted to wetland

The annual release of direct N_2O emissions due to the conversion of land to wetland was calculated with IPCC default value (Tier 1) using equation 11.2 and 11.8 of the IPCC GPG (2006):

$$N_2O_{Direct} - N = F_{SOM} \cdot EF_1$$

$$F_{SOM} = \sum_{LU} \left[\left(\Delta C_{Mineral,LUC} \cdot \frac{1}{R} \right) \cdot 1000 \right]$$

where:

EF_1=emission factor for N mineralised as a result of loss of soil carbon (default value = 0.01)

F_{SOM}= the net annual amount of N mineralised in mineral soils as a result of loss of soil carbon through change in land use or management, kg N

$\Delta C_{Mineral,LU}$ = average annual loss of soil carbon for each land-use type (LU), tonnes C

R = C/N ratio = ratio by mass of C to N in the soil organic matter = 12.

The annual release of indirect N_2O emissions due to the conversion of land to cropland was calculated with IPCC default value (Tier 1) using equation 11.10 of the IPCC GPG (2006):

$$N_2O_{(L)} - N = F_{SOM} \cdot Frac_{LEACH-(H)} \cdot EF_5$$

where:

$N2O_{(L)}$-N=annual amount of N_2O-N produced from leaching and runoff of N additions to managed soils in regions where leaching/runoff occurs, $kgN_2O\text{-}Nyr^{-1}$

F_{SOM}= the net annual amount of N mineralised in mineral soils as a result of loss of soil carbon through change in land use or management, kg N

EF_5=emission factor for N_2O emissions from N leaching result of loss of soil carbon (default value = 0.0075)

$Frac_{LEACH-(H)}$=fraction of all N added to/mineralised in managed soils in regions where leaching/runoff occurs that is lost through leaching and runoff, kgN (kg of N additions)$^{-1}$ (default value = 0.30)

6.6 Settlements (4.E)

6.6.1 Category description

In this category emissions/removals from land converted to settlements are considered.

In 2015, 25 678 ha of Luxembourg were settlements (Figure 1-17). The area in conversion status from “Land converted to Settlement” for a time period of 20 years ranges from 10 717 ha to 6 138 ha between the years 1990 and 2014 causing annual emission rates due to C stock changes of biomass and soils from 158.1 Gg $CO_2$to 72.6 Gg CO_2 (Table 1-29).

Annual LUCs to settlement occur from the sub-categories "Forestland", "Cropland", "Grassland", “Wetland” and "Other land".

Figure 6-17 – Trend of settlement and LUC to settlement (20 year conversion period) from 1990-2015

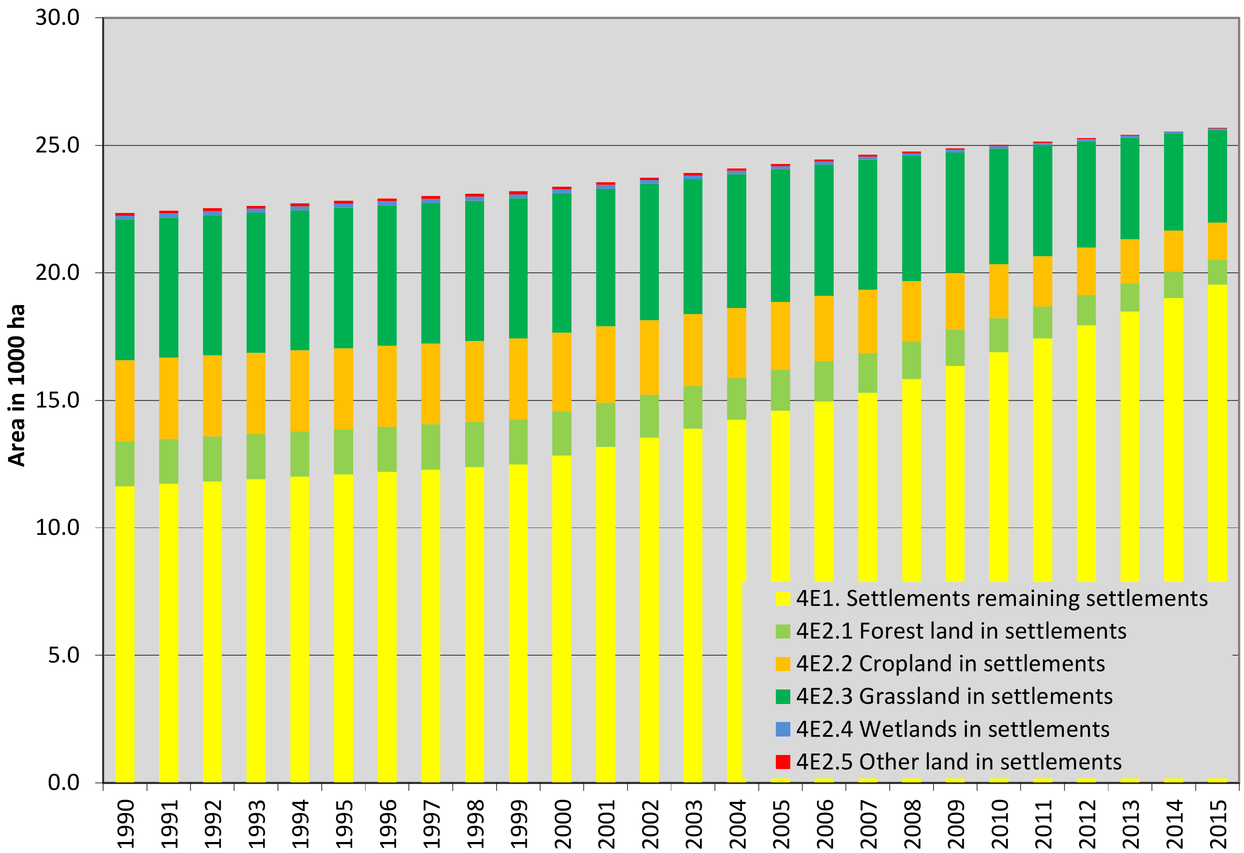


Table 6-29 – CO_2 removals/emissions from IPCC category 5E – Settlement from 1990-2015

4E - Settlement

Greenhouse gas emissions/removals (Gg CO_2 e)

Year	4E Total Settlement	4E1 Settlement -> Settlement	4E2 Land -> Settlement	4E2.1 FL -> Settlement	4E2.2 CL -> Settlement	4E2.3 GL -> to Settlement	4E2.4 WL -> Settlement	4E2.5 OL -> Settlement	N_2O (in CO_2 eq)
1990	158.12	NE	158.12	67.34	19.40	60.80	-1.43	-0.96	12.98
1991	158.12	NE	158.12	67.34	19.40	60.80	-1.43	-0.96	12.98
1992	158.12	NE	158.12	67.34	19.40	60.80	-1.43	-0.96	12.98
1993	158.12	NE	158.12	67.34	19.40	60.80	-1.43	-0.96	12.98
1994	158.12	NE	158.12	67.34	19.40	60.80	-1.43	-0.96	12.98
1995	158.12	NE	158.12	67.34	19.40	60.80	-1.43	-0.96	12.98
1996	158.12	NE	158.12	67.34	19.40	60.80	-1.43	-0.96	12.98
1997	158.12	NE	158.12	67.34	19.40	60.80	-1.43	-0.96	12.98
1998	158.12	NE	158.12	67.34	19.40	60.80	-1.43	-0.96	12.98
1999	158.12	NE	158.12	67.34	19.40	60.80	-1.43	-0.96	12.98
2000	140.67	NE	140.67	53.14	17.61	59.37	-1.35	-0.89	12.80
2001	139.30	NE	139.30	52.82	17.15	58.86	-1.30	-0.84	12.62
2002	137.94	NE	137.94	52.51	16.68	58.35	-1.25	-0.80	12.44
2003	136.57	NE	136.57	52.19	16.22	57.85	-1.20	-0.75	12.26
2004	135.20	NE	135.20	51.88	15.76	57.34	-1.15	-0.71	12.08
2005	133.83	NE	133.83	51.56	15.30	56.83	-1.10	-0.66	11.90
2006	132.47	NE	132.47	51.25	14.84	56.33	-1.05	-0.62	11.73
2007	131.10	NE	131.10	50.93	14.38	55.82	-1.00	-0.57	11.55
2008	99.18	NE	99.18	25.03	13.09	51.45	-0.93	-0.52	11.07
2009	95.39	NE	95.39	24.15	12.41	49.58	-0.87	-0.48	10.60
2010	91.59	NE	91.59	23.26	11.74	47.70	-0.80	-0.43	10.12
2011	87.80	NE	87.80	22.38	11.07	45.83	-0.74	-0.38	9.65
2012	84.00	NE	84.00	21.50	10.39	43.96	-0.68	-0.34	9.17
2013	80.21	NE	80.21	20.61	9.72	42.09	-0.61	-0.29	8.69
2014	76.41	NE	76.41	19.73	9.04	40.21	-0.55	-0.24	8.22
2015	72.62	NE	72.62	18.84	8.37	38.34	-0.48	-0.20	7.74
Trend 1990-2015	-54.08%	NA	-54.08%	-72.01%	-56.86%	-36.94%	-66.17%	-79.46%	-40.34%
Trend 2013-2015	-9.46%	NA	-9.46%	-8.57%	-13.88%	-8.90%	-20.83%	-32.15%	-10.93%

6.6.2 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation

For a detailed description of the development of the land transition matrix, please refer to section 1.1.3.3.

6.6.3 Land-use definitions and the classification systems used and their correspondence to the LULUCF categories

The LU89, LU99, LU07 and LU12 land use maps are the main data providers for the greenhouse gas reporting of IPCC category settlements. The selected parameters defining settlements are:

Land Use Class	Definition
Settlements	All developed land, including transportation and any size of human settlement unless already included under other categories.(IPCC GPG definition)

The settlement area in correspondence to the LULUCF category comprises the following subcategories:

- building land : sealed, partly sealed and unsealed area,
- parks and gardens,
- road, railway, track and excavation area,
- other, not further differentiated settlement area.

6.6.4 Methodological issues

6.6.4.1 Settlements remaining Settlements (4E1)

Due to a lack of data, this category has not been estimated.

6.6.4.2 Land Use Changes to Settlements (4E2)

<u>a) Changes in carbon stock in biomass of land converted to settlements:</u>
For the estimation of biomass stock and biomass growth in settlements, data from the municipality of Luxembourg was used. According to the magazine “EcoLogique n°1 2010” the municipality of Luxembourg has 18 500 trees in public unsealed areas which belong to the settlement category (*i.e.* are not forest or agricultural land). This amount was multiplied with annual growth rates of settlement trees as published in the IPCC GPG 2006 (Table 8.2). It was assumed that 75 % of these trees represent hardwood species for which according to this table 0.0100 t C/ha*y as annual growth rate per tree was taken. The other 25 % were assumed to be represented half-half by pine and spruce (0.0087 and 0.0092 t C/ha*y, respectively). The resulting annual growth rate was then divided by the related public unsealed area of Luxembourg city to get a per ha value. This resulted in an annual growth of trees at unsealed settlement areas of 0.25 t C/ha*y. For shrubs (each year 10 000 shrubs are planted at public areas of Luxembourg city) and annual plants, an annual growth rate of 0.125 and 3.2 t C/ha*y, respectively, at unsealed settlement areas was taken. Due to the lack of own data sources, these

values were derived from the related estimates for Austria which are based on a study for the city of Vienna (Dörflinger, Hietz, Maier, Punz, & Fussenegger, 1995). From these values and the percentage of unsealed area per ha settlement (40 % - derived by the composition of the settlement area according to LU99 and LU07) the annual C stock growth rate of biomass per settlement area (sealed plus unsealed) was estimated: 0.15 t C/ha*y for perennial plants and 1.29 t C/ha*y for annual plants. These annual biomass growth rates were assumed to be a valid average for settlement areas in Luxembourg and were used for areas of LUCs to settlement and for the 20 years of transition period after LUC (perennial plants) or for the first year after LUC only (annual plants).

For the biomass losses at LUC areas from settlements to other land uses the same data origins were used. The average biomass C stock at these areas was estimated to represent an equivalent of 20 years of growth of the tree and shrub biomass with the annual growth rates above and one biomass of annual plants. This results in a total biomass stock of 4.34 t C/ha to be present per ha settlement area. The rationale, for the 20-year growth period (because at 20 years trees are comparatively small), is that settlement areas with an equal distribution of older and younger biomass stocks are converted. Therefore, from a range of settlement areas with biomass stocks representing 1 year to 40 years of growth that are converted, the biomass stock from this range of land-use change areas is the average one of 20 years.

The methodology and activity data are described in chapter 1.2.4. However, the perennial plants in the settlement areas are estimated with a continued annual growth during the whole LUC transition period of 20 years as described in chapter 1.6.4.2.

For the calculation of the annual change in carbon stocks of living biomass in land converted to settlements the following equation IPCC GPG 2006 LULUCF Tier 1 method equation 2.15 and 2.16 was applied:

$$\textit{Annual change in carbon stock in biomass} = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L$$

$$\Delta C_{CONVERSION} = \sum_i \{(B_{AFTER_i} - B_{BEFORE_i}) \cdot \Delta A_{TO\_OTHERS_i}\} \cdot CF$$

where:

ΔC_G = annual change in carbon stocks in biomass due to growth on land converted to another land-use category (default value for perennial crops carbon accumulation rate is 0.15 t C $ha^{-1}yr^{-1}$ for perennial plants for a period of 20 years and 1.29 t C $ha^{-1}yr^{-1}$ for annual plants for a period of 1 year.

$B_{AFTER(i)}$ = stocks on land type i immediately after conversion, tonnes d.m. ha^{-1} (default value = 0).

$B_{BEFORE(i)}$ = stocks on land type i before conversion, tonnes d.m. ha^{-1} (value for carbon stock before conversion is 6.4 t C ha^{-1} for perennial cropland, 119.7 t C ha^{-1} for forestland, 6.3 t C ha^{-1} for grassland, 5.0 t C

ha^{-1} for annual cropland and 0.0 t C ha^{-1} for wetland and 0.0 t C ha^{-1} other land - see section 1.2.4.2.1 and **Table 1-20**).

ΔC_L = annual decrease in biomass carbon stocks due to losses from harvesting, fuel wood gathering and disturbances on land converted to other land-use category, in tonnes C yr^{-1} (default value = 0).

$\Delta T_{TO\_OTHERS(i)}$ = area of land use I converted to another land-use category in a certain year, ha yr^{-1}.

CF = carbon fraction of dry matter, tonne C (tonne d.m.)$^{-1}$.

b) Changes of carbon stock in dead wood and litter of land converted to settlements:

For the calculation of annual change in carbon stocks of dead wood and litter of land converted to settlements equation 2.23 from the GPG 2006 is used:

$$\Delta D_{DOM} = \frac{(C_n - C_o) \cdot A_{on}}{T_{on}}$$

where :

ΔC_{DOM} = annual change in carbon stocks in dead wood or litter (tonnes C yr^{-1})

C_o = dead wood/litter stock, under the old land-use category, tonnes C ha^{-1} (value dead wood in forest = 5.1 t C/ha*yr (average between forest inventory from 2000 and 2010) & default value for litter in forest = 19.2 t C/ha*yr (weighted average between default values of Table 2.2 of GPG 2006).

C_n = dead wood/litter stock, under the new land-use category, tonnes C ha^{-1} (default value = 0 for all land-use categories but forest)

A_{on} = area undergoing conversion from old to new land-use category, ha

T_{on} = time period of the transition from old to new land-use category, yr. The Tier 1 default is 20 years for carbon stock increases and 1 year for carbon losses

c) Changes in carbon stocks in soil of land converted to settlements

The following assumptions were taken to estimate the soil C stock in settlements. Sealed areas were assumed to have a soil C stock of 0 t C/ha. The unsealed settlement area (on average 40 % according to OBS99 and OBS07) was assumed to have the same soil C stock as grassland in Luxembourg (107 t C/ha). This resulted for total settlement in a soil C stock of 43 t C/ha which was used as initial soil C stock before LUC from settlement to other land uses or as final soil C stock after 20 years of transition after LUC to settlement.

According to the methodology described in 1.2.4.2.2, annual change in carbon stock of mineral soils = IEF(LUC_j) * conversion area, where :

$$IEF(LUC_{forestland\ ->\ settlements}) = -\ 3.393\ t\ C/\ ha\ *yr$$

$$IEF(LUC_{annual\ cropland\ ->\ settlements}) = -\ 1.609\ t\ C/\ ha\ *yr$$

$$IEF(LUC_{perennial\ cropland\ ->\ settlements}) = -\ 1.616\ t\ C/\ ha\ *yr$$

$$IEF(LUC_{grassland\ ->\ settlements}) = -\ 2.917\ t\ C/\ ha\ *yr$$

$$IEF(LUC_{wetland\ ->\ settlements}) = +\ 2.162\ t\ C/\ ha\ *yr$$

$$IEF(LUC_{other\ land\ ->\ settlements}) = +\ 2.162\ t\ C/ha\ *yr$$

EF(LUCj) = average yearly emission factor for carbon stock change in soil from land use change j

6.6.4.2.1 N_2O emissions in soils of land converted to settlements

The annual release of direct N_2O emissions due to the conversion of land to settlements was calculated with IPCC default value (Tier 1) using equation 11.2 and 11.8 of the IPCC GPG (2006):

$$N_2O_{Direct} - N = F_{SOM} \cdot EF_1$$

$$F_{SOM} = \sum_{LU} \left[\left(\Delta C_{Mineral,LUC} \cdot \frac{1}{R} \right) \cdot 1000 \right]$$

where:

EF_1=emission factor for N mineralised as a result of loss of soil carbon (default value = 0.01)

F_{SOM}= the net annual amount of N mineralised in mineral soils as a result of loss of soil carbon through change in land use or management, kg N

$\Delta C_{Mineral,LU}$ = average annual loss of soil carbon for each land-use type (LU), tonnes C

R = C/N ratio = ratio by mass of C to N in the soil organic matter = 12.

The annual release of indirect N_2O emissions due to the conversion of land to cropland was calculated with IPCC default value (Tier 1) using equation 11.10 of the IPCC GPG (2006):

$$N_2O_{(L)} - N = F_{SOM} \cdot Frac_{LEACH-(H)} \cdot EF_5$$

where:

$N2O_{(L)}$-N=annual amount of N_2O-N produced from leaching and runoff of N additions to managed soils in regions where leaching/runoff occurs, $kgN_2O\text{-}Nyr^{-1}$

F_{SOM}= the net annual amount of N mineralised in mineral soils as a result of loss of soil carbon through change in land use or management, kg N

EF_5=emission factor for N_2O emissions from N leaching result of loss of soil carbon (default value = 0.0075)

$Frac_{LEACH-(H)}$=fraction of all N added to/mineralised in managed soils in regions where leaching/runoff occurs that is lost through leaching and runoff, kgN (kg of N additions)$^{-1}$ (default value = 0.30)

6.7 Other Land (4.F)

6.7.1 Category description

In this category emissions/removals from land converted to other land are considered.

In 2015, 55 ha of Luxembourg were considered as other land (Figure 1-18). The area in conversion status from "Land converted to Other Land" for a time period of 20 years ranges from 56 ha to 14 ha between the years 1990 and 2015, causing annual emission rates due to C stock changes of biomass and soils from 1.8 Gg CO_2 to 0.3 Gg CO_2 (Table 1-30).

Annual LUCs to other land occur in the sub-categories "Forestland", "Cropland", "Grassland", "Settlements" and "Wetland".

Figure 6-18–Trend of Other Land and LUC to Other Land (20 year conversion period) from 1990-2015

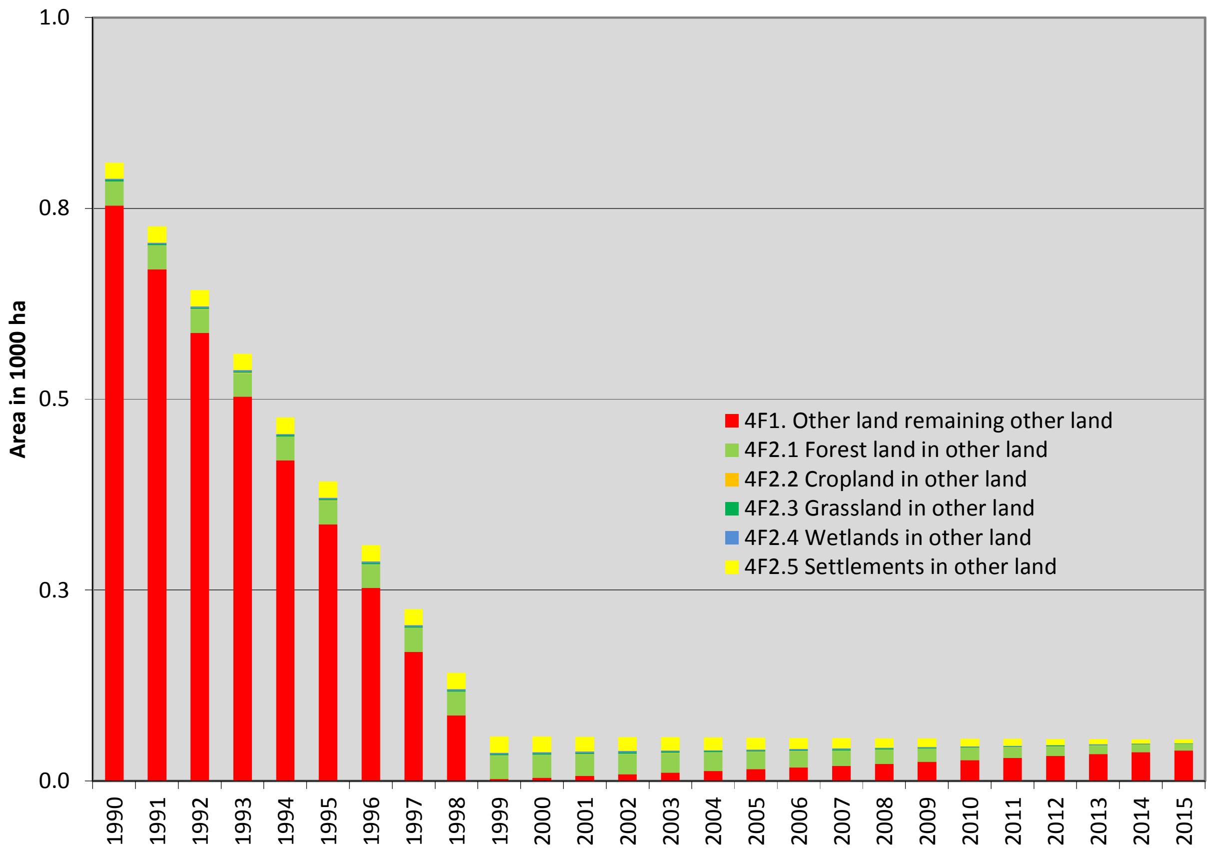


Table 6-30– CO_2 removals/emissions from IPCC category 4F – Other land from 1990-2014

4F - Other land *Greenhouse gas emissions/removals (Gg CO_2 e)*									
Year	**4F Total Other land**	**4F1 OL remaining OL**	**4F2 Land -> OL**	**4F2.1 FL -> OL**	**4F2.2 CL -> OL**	**4F2.3 GL -> OL**	**4F2.4WL -> OL**	**4F2.5 Settlement -> OL**	**N_2O (in CO_2 eq)**
1990	*1.78*	*NE*	*1.78*	*1.44*	*0.01*	*0.04*	*0.00*	*0.19*	*0.11*
1991	*1.78*	*NE*	*1.78*	*1.44*	*0.01*	*0.04*	*0.00*	*0.19*	*0.11*
1992	*1.78*	*NE*	*1.78*	*1.44*	*0.01*	*0.04*	*0.00*	*0.19*	*0.11*
1993	*1.78*	*NE*	*1.78*	*1.44*	*0.01*	*0.04*	*0.00*	*0.19*	*0.11*
1994	*1.78*	*NE*	*1.78*	*1.44*	*0.01*	*0.04*	*0.00*	*0.19*	*0.11*
1995	*1.78*	*NE*	*1.78*	*1.44*	*0.01*	*0.04*	*0.00*	*0.19*	*0.11*
1996	*1.78*	*NE*	*1.78*	*1.44*	*0.01*	*0.04*	*0.00*	*0.19*	*0.11*
1997	*1.78*	*NE*	*1.78*	*1.44*	*0.01*	*0.04*	*0.00*	*0.19*	*0.11*
1998	*1.78*	*NE*	*1.78*	*1.44*	*0.01*	*0.04*	*0.00*	*0.19*	*0.11*
1999	*1.78*	*NE*	*1.78*	*1.44*	*0.01*	*0.04*	*0.00*	*0.19*	*0.11*
2000	*1.00*	*NE*	*1.00*	*0.70*	*0.01*	*0.03*	*0.00*	*0.16*	*0.10*
2001	*0.96*	*NE*	*0.96*	*0.67*	*0.01*	*0.03*	*0.00*	*0.15*	*0.10*
2002	*0.92*	*NE*	*0.92*	*0.64*	*0.01*	*0.03*	*0.00*	*0.15*	*0.09*
2003	*0.88*	*NE*	*0.88*	*0.61*	*0.01*	*0.03*	*0.00*	*0.14*	*0.09*
2004	*0.84*	*NE*	*0.84*	*0.58*	*0.01*	*0.03*	*0.00*	*0.13*	*0.09*
2005	*0.80*	*NE*	*0.80*	*0.56*	*0.01*	*0.03*	*0.00*	*0.12*	*0.08*
2006	*0.76*	*NE*	*0.76*	*0.53*	*0.01*	*0.03*	*0.00*	*0.11*	*0.08*
2007	*0.72*	*NE*	*0.72*	*0.50*	*0.01*	*0.03*	*0.00*	*0.11*	*0.07*
2008	*0.61*	*NE*	*0.61*	*0.41*	*0.01*	*0.03*	*0.00*	*0.10*	*0.07*
2009	*0.56*	*NE*	*0.56*	*0.38*	*0.01*	*0.03*	*0.00*	*0.09*	*0.06*
2010	*0.52*	*NE*	*0.52*	*0.35*	*0.00*	*0.02*	*0.00*	*0.08*	*0.06*
2011	*0.47*	*NE*	*0.47*	*0.32*	*0.00*	*0.02*	*0.00*	*0.07*	*0.05*
2012	*0.42*	*NE*	*0.42*	*0.29*	*0.00*	*0.02*	*0.00*	*0.06*	*0.04*
2013	*0.38*	*NE*	*0.38*	*0.26*	*0.00*	*0.02*	*0.00*	*0.05*	*0.04*
2014	*0.33*	*NE*	*0.33*	*0.23*	*0.00*	*0.02*	*0.00*	*0.05*	*0.03*
2015	*0.29*	*NE*	*0.29*	*0.20*	*0.00*	*0.02*	*0.00*	*0.04*	*0.03*
Trend 1990-2015	*-83.89%*	*NA*	*-83.89%*	*-86.06%*	*-57.15%*	*-56.77%*	*NA*	*-79.56%*	*-73.39%*
Trend 2013-2015	*-24.22%*	*NA*	*-24.22%*	*-23.02%*	*-17.93%*	*-17.88%*	*NA*	*-30.78%*	*-26.68%*

6.7.2 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation

For a detailed description of the development of the land transition matrix, please refer to section 1.1.3.3.

6.7.3 Methodological issues

6.7.3.1 Other Land remaining Other Land (4F1)

Due to a lack of required data on carbon stock changes, this category has not yet been estimated.

6.7.3.2 Land Use Changes to Other Land (4F2)

6.7.3.2.1 Biomass and soil

According to the land use assessment systems OBS89, OBS99 and OBS07, other land in Luxembourg is constituted by rocks, scree slopes and gravel areas. It is assumed that these areas have no C stock in biomass and soil, so 0 was used as previous or final C stock at areas of LUCs from or to other land, respectively.

For the calculation of the annual change in carbon stocks of living biomass in land converted to wetland the following equation IPCC GPG 2006 LULUCF Tier 1 method equation 2.15 and 2.16 was applied:

$$\textit{Annual change in carbon stock in biomass} = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L$$

$$\Delta C_{CONVERSION} = \sum_i \left\{ \left(B_{AFTER_i} - B_{BEFORE_i} \right) \cdot \Delta A_{TO\_OTHERS_i} \right\} \cdot CF$$

where :

ΔC_G = annual change in carbon stocks in biomass due to growth on land converted to another land-use category (default value for perennial crops carbon accumulation rate is 0.0 t C $ha^{-1}yr^{-1}$).

$B_{AFTER(i)}$ = stocks on land type i immediately after conversion, tonnes d.m. ha^{-1} (default value = 0).

$B_{BEFORE(i)}$ = stocks on land type i before conversion, tonnes d.m. ha^{-1} (value for carbon stock before conversion is 6.4 t C ha^{-1} for perennial cropland, 119.7 t C ha^{-1} for forestland, 6.3 t C ha^{-1} for grassland, 4.3 t C ha^{-1} for settlements, 5.0 t C ha^{-1} for annual cropland and 0.0 t C ha^{-1} other land - see section 1.2.4.2.1 and **Table 1-20**).

ΔC_L = annual decrease in biomass carbon stocks due to losses from harvesting, fuel wood gathering and disturbances on land converted to other land-use category, in tonnes C yr^{-1} (default value = 0).

$\Delta T_{TO\_OTHERS(i)}$ = area of land use I converted to another land-use category in a certain year, ha yr^{-1}.

CF = carbon fraction of dry matter, tonne C (tonne d.m.)$^{-1}$.

b) Changes of carbon stock in dead wood and litter of land converted to other land:

For the calculation of annual change in carbon stocks of dead wood and litter of land converted to other land equation 2.23 from the GPG 2006 is used:

$$\Delta D_{DOM} = \frac{(C_n - C_o) \cdot A_{on}}{T_{on}}$$

where :

ΔC_{DOM} = annual change in carbon stocks in dead wood or litter (tonnes C yr^{-1})

C_o = dead wood/litter stock, under the old land-use category, tonnes C ha^{-1} (value dead wood in forest = 5.1 t C/ha*yr (average between forest inventory from 2000 and 2010) & default value for litter in forest = 19.2 t C/ha*yr (weighted average between default values of Table 2.2 of GPG 2006).

C_n = dead wood/litter stock, under the new land-use category, tonnes C ha^{-1} (default value = 0 for all land-use categories but forest)

A_{on} = area undergoing conversion from old to new land-use category, ha

T_{on} = time period of the transition from old to new land-use category, yr. The Tier 1 default is 20 years for carbon stock increases and 1 year for carbon losses

c) Changes in carbon stocks in soil of land converted to other land

According to the methodology described in 1.2.4.2.2, annual change in carbon stock of mineral soils = $IEF(LUC_j)$ * conversion area, where :

$$IEF(LUC_{forestland \rightarrow other\ land}) = -5.554\ t\ C/ha\ *yr$$

$$IEF(LUC_{perennial\ cropland \rightarrow other\ land}) = -3.778\ t\ C/ha\ *yr$$

$$IEF(LUC_{annual\ cropland \rightarrow other\ land}) = -3.770\ t\ C/ha\ *yr$$

$$IEF(LUC_{grassland \rightarrow other\ land}) = -5.079\ t\ C/ha\ *yr$$

$$IEF(LUC_{settlements \rightarrow other\ land}) = -2.162\ t\ C/ha\ *yr$$

$$IEF(LUC_{wetland \rightarrow other\ land}) = 0.0\ t\ C/ha\ *yr$$

IEF(LUCj) = average yearly emission factor for carbon stock change in soil from land use change j

6.7.3.2.2 N_2O emissions in soils of land converted to other land

The annual release of direct N_2O emissions due to the conversion of land to other land was calculated with IPCC default value (Tier 1) using equation 11.2 and 11.8 of the IPCC GPG (2006):

$$N_2O_{Direct} - N = F_{SOM} \cdot EF_1$$

$$F_{SOM} = \sum_{LU} \left[\left(\Delta C_{Mineral,LUC} \cdot \frac{1}{R} \right) \cdot 1000 \right]$$

where:

EF_1=emission factor for N mineralised as a result of loss of soil carbon (default value = 0.01)

F_{SOM}= the net annual amount of N mineralised in mineral soils as a result of loss of soil carbon through change in land use or management, kg N

$\Delta C_{Mineral,LU}$ = average annual loss of soil carbon for each land-use type (LU), tonnes C

R = C/N ratio = ratio by mass of C to N in the soil organic matter = 12.

The annual release of indirect N_2O emissions due to the conversion of land to cropland was calculated with IPCC default value (Tier 1) using equation 11.10 of the IPCC GPG (2006):

$$N_2O_{(L)} - N = F_{SOM} \cdot Frac_{LEACH-(H)} \cdot EF_5$$

where:

$N2O_{(L)}$-N=annual amount of N_2O-N produced from leaching and runoff of N additions to managed soils in regions where leaching/runoff occurs, kgN_2O-Nyr^{-1}

F_{SOM}= the net annual amount of N mineralised in mineral soils as a result of loss of soil carbon through change in land use or management, kg N

EF_5=emission factor for N_2O emissions from N leaching result of loss of soil carbon (default value = 0.0075)

$Frac_{LEACH-(H)}$=fraction of all N added to/mineralised in managed soils in regions where leaching/runoff occurs that is lost through leaching and runoff, kgN (kg of N additions)$^{-1}$ (default value = 0.30)

6.8 Uncertainties and time-series consistency

6.8.1 Uncertainties in relation to the emission factors extracted from the NFI

In order to calculate the uncertainties within the forestland category a separate study was commissioned in order to estimate the errors related to the individual emission factors extracted from the NFI (Bauwens, 2015).

There are many sources of uncertainty in forest biomass estimates (section 3.1.5 of the volume1 of the 2006 IPPC guidelines) and many intermediate steps are necessary to estimate the individual parameters (biomass, biomass growth rate, biomass expansion factor etc) extracted from NFI data. An error is associated with each of these intermediate steps. The global uncertainty related to any other parameter combines all those individual uncertainties. Due to the nature of the NFI (sampling method) the "statistical random sampling error" is also part of the whole uncertainty assessment. The error related to the estimations is based on statistical formula relating the standard error of the mean and the t-student variable with a risk α of 5 % as recommended by IPCCC guidelines.

$$\widehat{SE}_x = \frac{\hat{\sigma}_x}{\sqrt{n}} = \frac{\sum(x - \bar{x})^2}{\sqrt{(n-1)n}}$$

$$Error\ (\%) = t_{1-\frac{\alpha}{2}} \cdot \frac{\widehat{SE}_x}{\bar{x}}$$

where:

$\widehat{SE}_x$, the estimated standard error of the variable x

$\hat{\sigma}_x$, the estimated standard-deviation of the variable x;

n the total number of sample;

$\bar{x}$ the mean of the variable x;

t the t-student variable with a risk α.

In order to estimate carbon stock the NFI used species-specific values for biomass expansion factors, wood density and below-ground to above-ground biomass rations (R). The biomass expansion factors are based on a detailed study by (Dagnelies, Palm, & Rondeux, 2013) and according to expert judgement the error linked to these factors is estimated at ±15%. The below-ground to above-ground biomass rations (R) are based on a study by (Vande Walle, et al., 2005) which itself is based on a comparison of values used across Europe. Hence the default error values of ±93% for coniferous wood (value R=0.2 [0.12-0.49]) and ±56% for deciduous wood (value R=0.24 [0.17-0.44]) were used. The values of wood density chosen for the NFI are based on (Wagenführ & Schreiber, 1985). Her as well the default value for uncertainty from IPCC guidelines was chosen. The latter one is estimated to be between 10-40% and hence the value was set at ±25%. The uncertainty on the carbon factor is also based on the default value of ±5.3 % (0.47 [0.44-0.49]). For litter the default emission factor and associated uncertainty were extracted from the IPCC guidelines (weighted average of deciduous 16 tC/ha^{-1} (5 tC/ha^{-1} - 31 tC/ha^{-1}) and coniferous 26 tC/ha^{-1} (10 tC/ha^{-1} – 48 tC/ha^{-1}).

Those calculations translated into the following errors for the individual emission factors:

Table 6-31 – errors linked to emission NFI factors (t C/ha)

emission factor	value	error
Above ground biomass growth coniferous trees	7.83 tC/ha^{-1}	±30%
Above ground biomass growth deciduous trees	4.40 tC/ha^{-1}	±30%
Below ground biomass growth coniferous trees	1.54 tC/ha^{-1}	±97.3%
Below ground biomass growth deciduous trees	1.01 tC/ha^{-1}	±63.8%
Above ground biomass growth trees 0-20y	5.53 tC/ha^{-1}	±32.7%
Below ground biomass growth trees 0-20y	1.12 tC/ha^{-1}	±81.2%
Dead wood	11.96 tC/ha^{-1}	±36.6%
Litter	19.20 tC/ha^{-1}	±77.2%
Biomass carbon stocks in forests (above-and below ground)	119.7 tC/ha^{-1}	±80.3%

The data on wood harvest is based on data extracted from the NFI as well as from yearly data of wood sales from public forests. The error applied on those figures is the default value of ±20% (IPPC guideline page 4.19).

6.8.2 Uncertainties of activity data in relation to area (activity data)

The accuracy assessment was carried out for the land use maps that were developed in 2012 and was based on aerial photographs and LUCAS 2012 data/photographs, provided by

Eurostat. The quality assessment consisted in controlling 2 200 randomly sampled points (200 per class) enabling to detect omission and commission errors of these points by another expert based on the reference information. This interpretation has been compared to the result of the change detection.

In addition LC/LU (Land Cover/Use changes) data of about 215 LUCAS (Land Use/Cover Area statistical Survey) points have been compared to LULUCF12 data, using the LC/LU information and the photographs taken during the LUCAS survey in 2012.

In total out of the 2 415 points controlled, 48 were wrongly classified meaning that an overall accuracy of 98.01 % was achieved.

This does however not take into account the error in relation to the underlying accuracy of the polygons of the LU2007 maps. The polygons of the 2007 layer were established with a MMU (Minimum Mapping Unit) of 1 500 m². Hence the overall error is determined by the accuracy assessment of 2012 (with regards to land use) as well as the minimum mapping unit used for establishing the land use maps in 2007.

The translation of the MMU in overall error is unfortunately not that simple. The individual categories (settlements, forests etc) occur in different cluster sizes, depending on their composition. This leads to disparate class accuracy. For example, forest areas are typically large and relatively heterogeneous; thus, one would expect that these areas would become more uniform due to the smoothing effect of the resampling filter. This uniformity could result in those areas having a higher accuracy.

Luxembourg is planning on commissioning the creation of a new OBS (land use map). As part of this contract a detailed uncertainty analysis will also be carried out. According to the IPPC guidelines (Chapter 4 page 4.20) the uncertainties in forest areas is approximately 3%. Considering the method described her above the overall uncertainty on areas determined with satellite imagery is most likely lower. It would however be extremely difficult to calculate the exact value and hence the decision was taken to use the default value for uncertainty of ±3%.

6.8.3 Uncertainties of emission factors from soil samples

According to the methodology described in 1.2.4.2.2 carbon stock changes have been measured for the individual regions and soil covers in Luxembourg. The error computed here represents the standard deviation of the individual sample plots multiplied by two. This is in line with the first footnote of Table 2.3 (IPPC Guidelines – Chapter 2) where "a nominal error estimate of

± 90% (expressed as 2x standard deviations as percent of the mean)" was provided for standard soil organic carbon stocks.

Table 6-32 – Carbon soil stocks and errors per land use and soil type (t C/ha) in Luxembourg

Soil type	Carbon soil stocks per land use and soil type (t C/ha) and error (%)			
	Cropland (Annual Cropland)	Grassland	Forestland	Vineyard (Perennial cropland)
Oesling	91.5 ± 27%	89.2 ± 13%	132.2 ± 20%	71.0 ± 0%
Buntsandstein	66.7 ± 29%	82.8 ± 26%	112.1 ± 41%	73.5 ± 0%
Dolomies du Muschelkalk	85.5 ± 35%	112.1 ± 28%	117.0 ± 20%	77.9 ± 0%
Calcaires du Bajocien	75.2 ± 33%	122.0 ± 16%	111.5 ± 21%	77.7 ± 0%
Grès de Luxembourgs	50.7 ± 25%	83.3 ± 31%	80.6 ± 23%	76.2 ± 0%
Dépôts limoneux sur Grès	58.6 ± 36%	99.4 ± 35%	95.7 ± 25%	75.1 ± 0%
Argiles du Lias inf. et moyen	69.8 ± 35%	121.6 ± 21%	95.2 ± 21%	75.7 ± 0%
Argiles lourdes du Keuper	67.7 ± 40%	121.3 ± 23%	102.6 ± 22%	76.0 ± 0%
Argiles lourdes des schistes bitumineux	88.2 ± 46%	145.7 ± 14%	104.8 ± 17%	NA
Others	80.7 ± 61%	110.8 ± 28%	126.6 ± 55%	74.9 ± 0%
ALL	**76.8 ± 48%**	**107.4 ± 37%**	**110.7 ± 42%**	**73.5 ± 4%**

It is important to highlight that the error on the mean is very low because the amount of soil samples is very high. Hence the confidence interval on the mean value is also very narrow (the probability that the average value measured corresponds to the true average value is hence very high). If the total carbon content was calculated as a total figure for the whole country the error would also be very low. For the purpose of IPPC calculations the carbon soil contents are however used to determine carbon soil changes due to land use change at parcel level. This means that the variability of the samples has to be taken into account. Compared to the error of the mean the variability of the dataset is however very high. Because the variability has to be considered, when calculating carbon stock changes due to land use change, the overall error on carbon stock changes associated with land is very high. This error cannot be reduced by taking more soil samples. The only way to reduce the error would be to cross-reference the soil samples taken with the land use change maps in order to only consider those soil samples which were taken on those parcels where the land use change took place. This would however require an important computing effort and it is not guaranteed that the error would be reduced because even at parcel level the variability of results in soil carbon content can be very high.

Table 6-33 – land use change matrix for soil carbon emission factors with errors (t C/ha*yr)

from \ to	Forest land	Annual Cropland	Perennial Cropland	Grassland	Wetland	Settlement	Other land
Forest land	0	-1.8 ±176%	-1.2 ±196%	-0.5 ±672%	-5. ±306%	-3.4 ±306%	-5.6 ±306%
Annual Cropland	1.8 ±176%	0	0.5 ±433%	1.3 ±221%	-3.8 ±306%	-1.6 ±306%	-3.8 ±306%

Perennial Cropland	1.2 ±196%	-0.5 ±433%	0	1.5 ±138%	-3.8 ±306%	-1.6 ±306%	-3.8 ±306%
Grassland	0.5 ±672%	-1.3 ±221%	-1.5 ±138%	0	-5.1 ±306%	-2.9 ±306%	-5.1 ±306%
Wetland	5.6 ±306%	3.8 ±306%	3.8 ±306%	5.1 ±306%	0	2.2 ±306%	0.000
Settlement	3.4 ±306%	1.6 ±306%	1.6 ±306%	2.9 ±306%	-2.2 ±306%	0	-2.2 ±306%
Other land	5.6 ±306%	3.8 ±306%	3.8 ±306%	5.1 ±306%	0.0 ±306%	2.2 ±306%	0 ± 27%

Table 1-33 indicates the errors of the emission factors used for calculation of soil carbon stock changes. The errors are calculated by taking into account the individual errors of carbon soil content categories as well as the variability. As the matrix is giving the difference between two levels of carbon soil contents the relative errors (in %) becomes very high. For the categories wetland, settlements, grassland and other land the average error of the remaining categories was chosen.

6.8.4 Uncertainties of emission factors from biomass carbon stocks

Table 6-34 – errors linked to emission factors of biomass carbon stock (t C/ha)

emission factor	value	error	origin
biomass carbon stock for perennial cropland (see **Table 1-21**)	6,3 tC/ha^{-11}	±75%	IPPC default value (Table 5.1)
biomass carbon stock for annual cropland	5,0 tC/ha^{-1}	±75%	IPPC default value (Table 5.9)
biomass carbon stock for grassland	6,3 tC/ha^{-1}	±75%	IPPC default value (Table 6.4)
biomass carbon stock for wetland	0,0 tC/ha^{-1}	±0%	
biomass carbon stock for settlements	4,3 tC/ha^{-1}	±75%	expert judgement
biomass carbon stock for other land	0,0 tC/ha^{-1}	±0%	

The error for N2O emissions is a combination of the error on the C/N ratio (±40%) and the error of the linked calculation of carbon emission.

6.8.5 Overall uncertainty assessment

Compared to the other sectors the LULUCF sector is particular as it does not only cover CO_2 emission but also CO_2 removals. This means that the calculated uncertainties are best evaluated for emissions and removals separately in order to get a good understanding of the quality of the data collected.

Figure 6-19 – errors in the LULUCF sector by land use categories and by removals and emissions

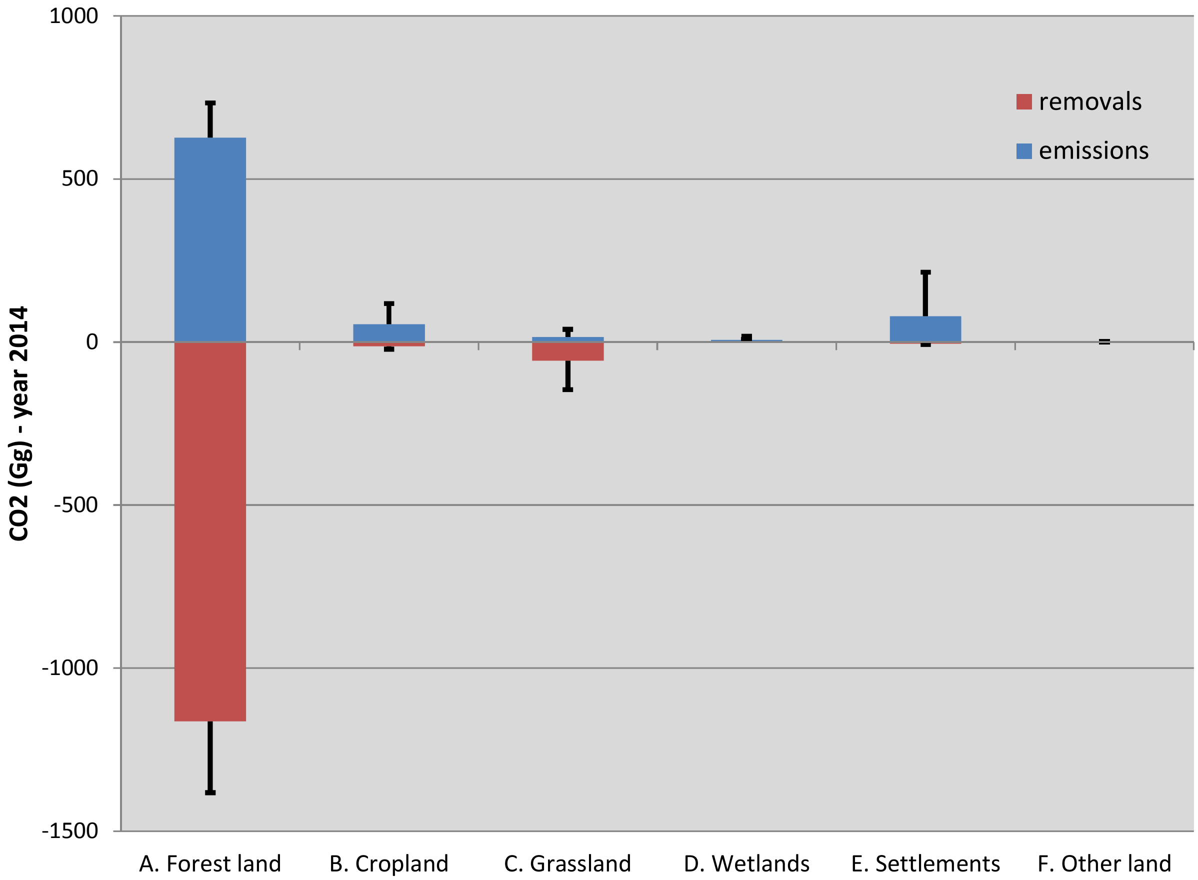
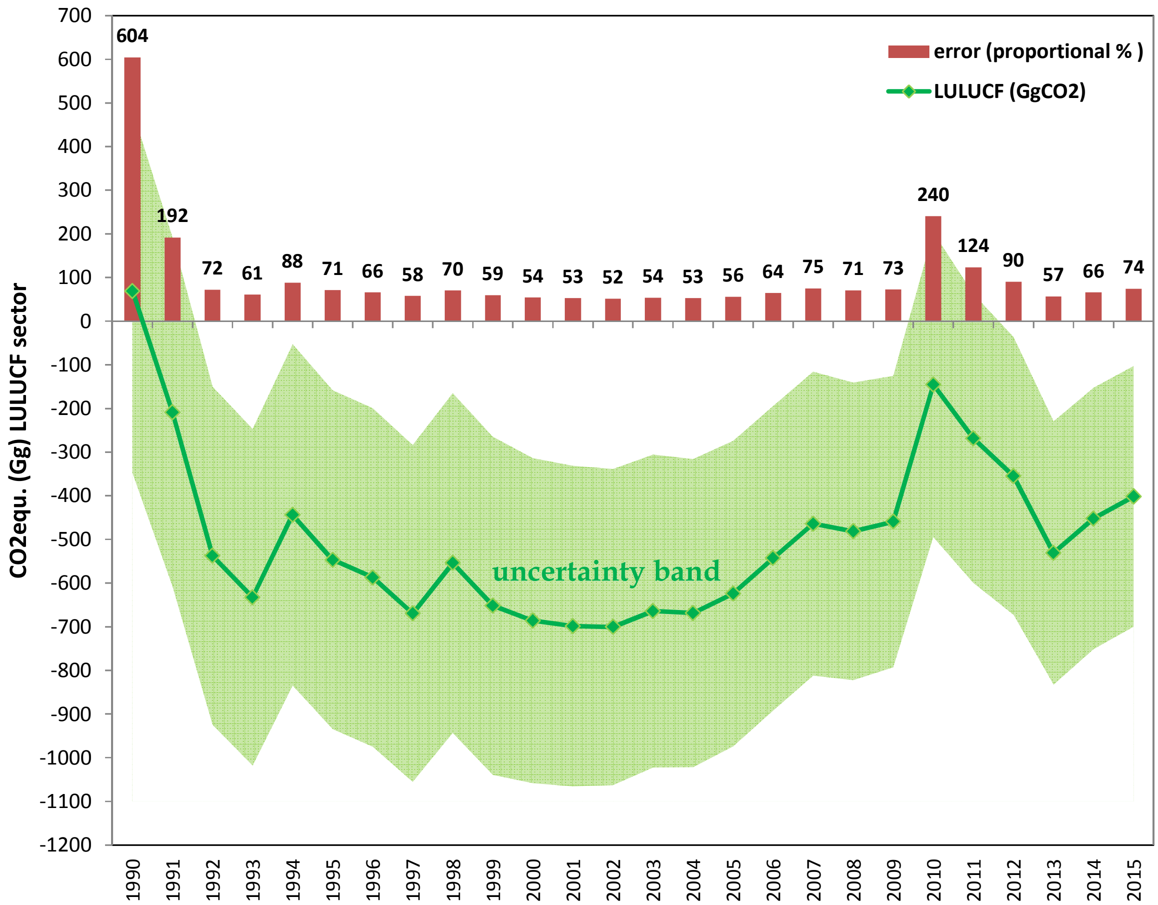


Figure 1-19 highlights how the overall LULUCF sector is mainly influenced by emissions and removals in the forest sector. The error on emissions and removals for the forest sector are ±17 % and ±19 %. The other land use categories contribute a lot less to the overall emissions and removals of the LULUCF sector. The errors within those categories are proportionally also higher. The settlement categories is characterised by high emission due to soil carbon loss resulting from urbanisation. Considering that the errors associated to soil carbon change are very high the results of these categories are very high.

For the year 2014 the proportional error is 74 %. This value is however strongly dependant on the proportion of removals and emissions and tends towards infinity as the sum of removals and emissions tends to zero. This is very striking when comparing the year 1990 with any of the years between 1999 and 2006 in **Figure 1-20**. The absolute error is more or less constant but the proportional error is much higher for the year 1990 where the sum of emissions and removals was close to zero. In order to qualify the errors of the LULUCF sector it would be more useful to assess the error separately for the emissions and removals as it is done in Figure 1-19. The proportional error of the LULUCF sector can only be used to assess the error on the overall result but cannot be used to assess the quality of the underlying data.

Figure 6-20 – absolute and proportional error in relation to total emissions in LULUCF sector

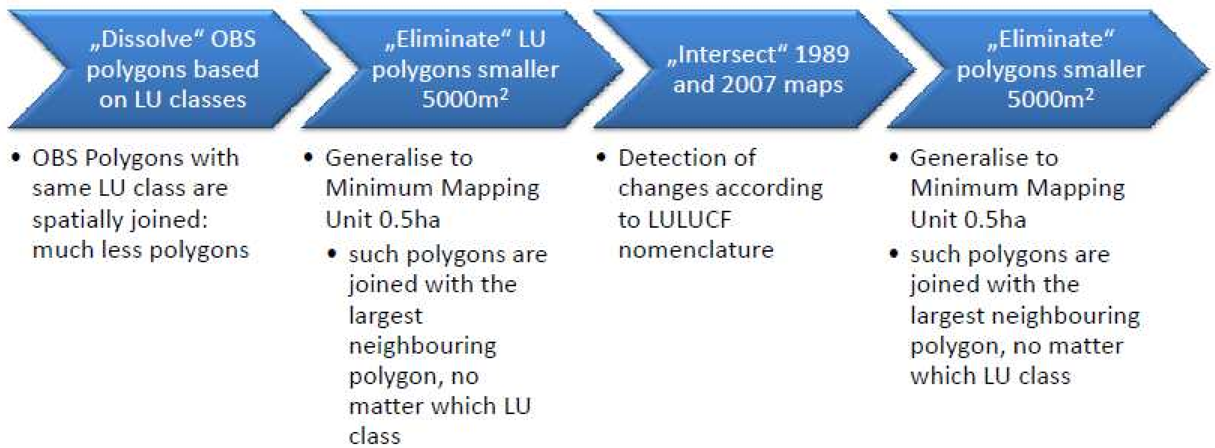


6.8.6 Time series consistency

Within the LULUCF land use change matrixes are the most critical type of data when analysing time series consistency. Other emission factors have been used consistently for the entire time series. When, for example new emission factors from the second NFI were being introduced the entire time series was subsequently being updated in order to reflect those new emission factors (e.g. growth rates).

In OBS 89 the minimum mapping unit (MMU) was set to 1 500 m². In OBS99 the official MMU was 2 500 m² for surface features, respectively 1 500 m² for several objects of specific biologic interest. For the 2007 update the MMU was set to 500 m². For the 2012 update the same polygons of the 2007 OBS were kept and only land used changes were recorded with a minimum areas size of 1 500 m².

Figure 6-21 – Geodata processing methodology to guarantee time series consistency



In order to guarantee time series consistency when working with land use maps of different MMU the individual land use maps were modified in order to have the same MMU as shown on Figure 1-21. The resulting land use changes were also caped to polygons greater than 1 500 m².

The total area as computed from the GIS data sets differs slightly from the official area of the Luxembourg territory. This is simply due to resolution /scale and data processing inaccuracies in the data sets. Therefore, the areas derived from the geodata have been put in relation to the official area of Luxembourg (258 600 ha). It means that all areas resulting from the geodata processing are proportional to the official territory of Luxembourg that is 2 586 km².

6.9 Harvested Wood Products (4.G)

6.9.1 Approach

For reasons of consistency, the calculation was carried out in keeping with the rules in Chapter 2.8 of the 2013 IPCC KP Supplement (IPCC 2014). Pursuant to footnote 12 in table sheet 4.G s1 of the Common Reporting Format in Annex II of Decision 24/CP.19 (UNFCCC 2014), IPCC Guidelines other than the 2006 IPCC Guidelines may be used for the chosen approach (approach B) if they are in keeping with that approach. The system boundaries described in the rules of the 2013 IPCC KP Supplement, for estimation of the contribution of HWP, are consistent with the system boundaries of the approach referred to in Table 12.1 of the 2006 IPCC Guidelines with variable 2A.

6.9.2 Activity data: production, imports and exports of industrial roundwood

Definition of industrial roundwood (FAO, 2015): "Industrial roundwood is roundwood that will be used in the production of other goods and services (except as a source of fuel). It includes all roundwood except wood fuel. In the production statistics, it represents the sum of: sawlogs and veneer logs; pulpwood, round and split; and other industrial roundwood. Data on industrial roundwood production are not available for a number of countries and have been estimated by converting the volume of products produced in the country to the volume of roundwood required to produce that volume (the roundwood equivalent)".

A detailed analysis of the quantities of roundwood produced, imported and exported is required in order to estimate the annual fraction of the feedstock coming from domestic harvest for the HWP categories sawnwood and wood-based panels. The quantity of industrial roundwood produced minus the quantity of industrial roundwood exported is assumed to be used in order to produce the different types of HWP categories. The share of industrial roundwood for the domestic production of HWP originating from domestic forests is calculated for each year with the following equation (Hirashi, et al., 2014):

$$f_{IRW}(i) = \frac{IRW_P(i) - IRW_{EX}(i)}{IRW_P(i) + IRW_{IM}(i) - IRW_{EX}(i)} \qquad \textbf{(Equation 6-1)}$$

Figure 6-22 import, export and production of industrial roundwood in Luxembourg (origin: FAO and forest agency)

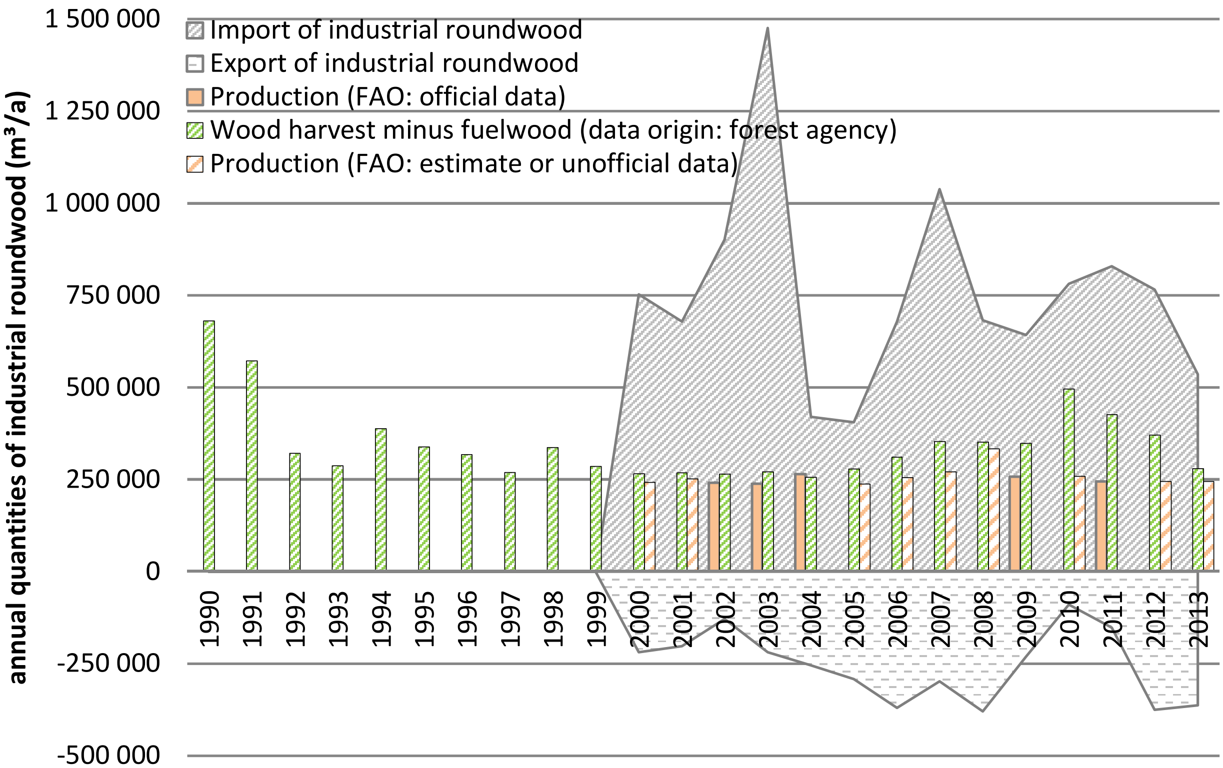


Figure 1-24 is showing data retrieved from the FAO database as well as data submitted by the forest agency (represented in green). In order to use the first order decay function described in the guidelines (Hirashi, et al., 2014) data for the main HWP categories need to date back, ideally, to 1960. For most member states data on HWP categories in the FAO database date back to 1960. For Luxembourg this is unfortunately not the case as all the data on HWP categories only dates back to the year 2000. Moreover the data is not complete as official data used by the FAO on production data is only available for the years 2001-2004, 2009 and 2011. The remaining data have been estimated and are thus not very reliable as the quantity of wood extracted from the forests can strongly change between years.

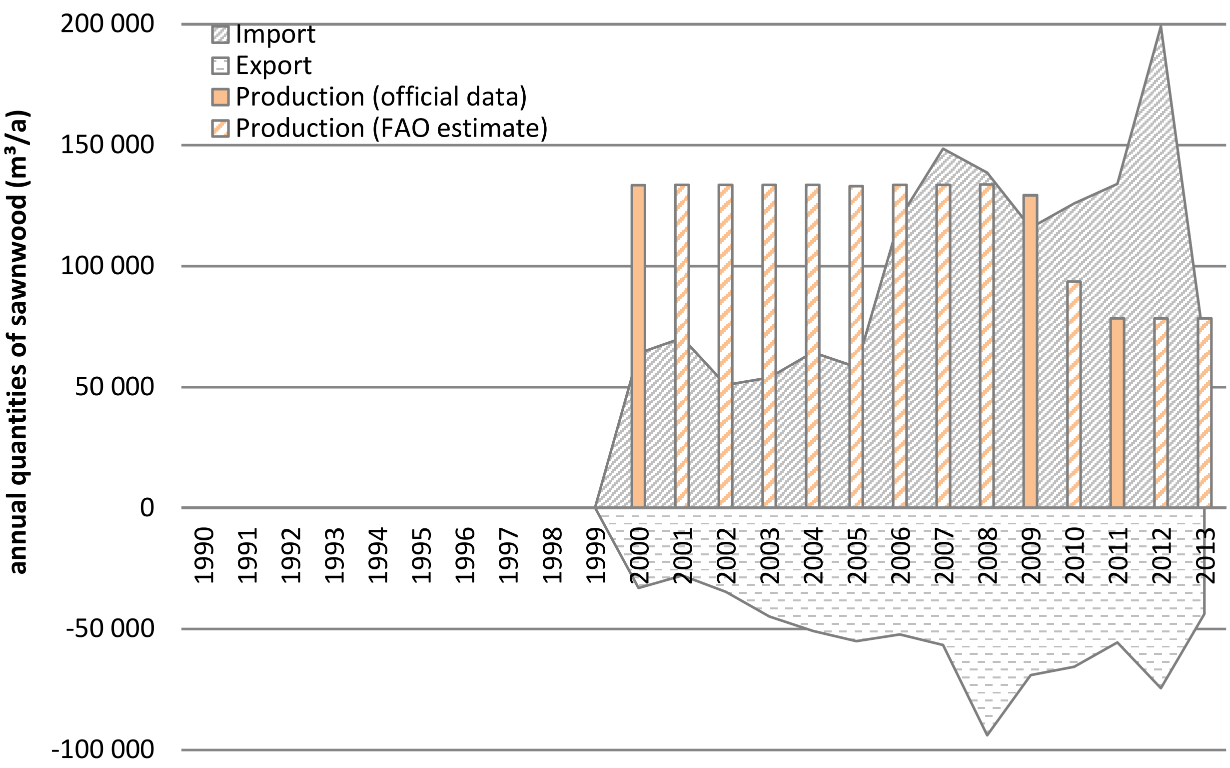
Alongside the data from the FAO database the quantity of wood harvested (minus fuelwood) is also shown in the same figure. This set of data seems more reliable as it shows the exact figure for wood removed in public forest (minus fuelwood) and an estimation of the wood removed in private forests (see section 1.2.4.1.1). With regards to production figures it seems more reasonable to take these official figures for further calculations instead of the production figures issued by the FAO. (During the process of data collection the Luxembourg statistical institute

(STATEC) and the forest agency have also been involved in order to coordinate the publication of official data on forest harvest).

The analysis of import and export figures is showing some interesting patterns which have a strong influence on the calculation of the share of industrial roundwood for the domestic production of HWP originating from domestic forests (Equation 1-1). The trend shows that import figures are in general higher than production figures and export figures are on a similar scale than production data. Both export and import figures show very strong fluctuations which would make it almost impossible to extrapolate those dataset to years previous of 2000. For the year 2008 production (FAO data & data by forest agency) figures are even inferior to export figures. This suggests that a certain amount of wood would transit through Luxembourg, being first imported and subsequently exported again.

6.9.3 Activity data: production, imports and exports of sawnwood

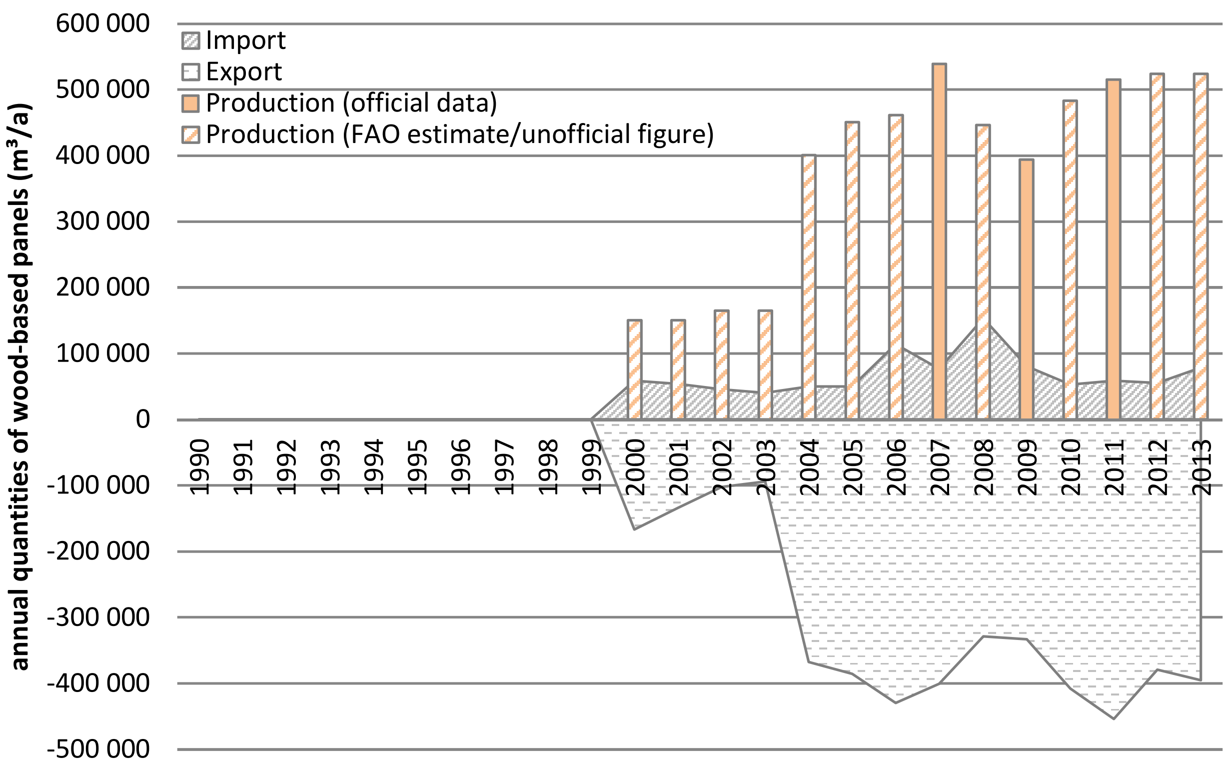
Figure 6-23: import, export and production of sawnwood in Luxembourg (origin: FAO)



All the data available for sawnwood has been taken from the FAO database. Official data is only available for the years 2000, 2009 and 2011. It is not clear yet where the official production data on sawnwood come from but it seems that the information is generally collected through the JFSQ questionnaire which is submitted by the forest agency to the FAO. The JFSQ questionnaire is often prefilled with data on import and export figures from Eurostat. Production figures of the officially submitted data are often just considered to be the difference between exports and imports (see data for year 2011). Figure 1-23 clearly highlight how unreliable the dataset for Luxembourg and questions whether the calculation on HWP can be based on this dataset.

6.9.4 Activity data: production, imports and exports of wood-based panels

Figure 6-24: import, export and production of wood-based panels in Luxembourg (origin: FAO)



All the data available for wood-based panels has been taken from the FAO database. Official data is only available for the years 2007, 2009 and 2011. It is unclear where the official production data for wood-based panels is originating but here as well the information is generally collected through the JFSQ questionnaire which is submitted by the forest agency to the FAO.

Luxembourg is home to one major company who has been producing wood-based panels since 1995. This producer has a yearly output capacity of:

- MDF (medium-density fibreboard) of 240 000 m^3/a (Svehla & Winter, 2013)
- OSB (oriented strand board): 160 000 m^3/a

Most of the production is exported to other countries and considering that the production data is not complete the export figures could be used as production figures. The problem would still remain that data is only available from 2000 onwards.

The carbon pool calculated for wood-based panel could be interesting to calculate for Luxembourg if the share of wood coming from forests inside Luxembourg was known. As it was discussed in section 1.9.2 the data on industrial roundwood is too much skewed by high import and export figures to be used in order to estimate the share coming from domestic harvest.

6.9.5 Activity data: production, imports and exports of wood pulp

Definition of wood pulp:

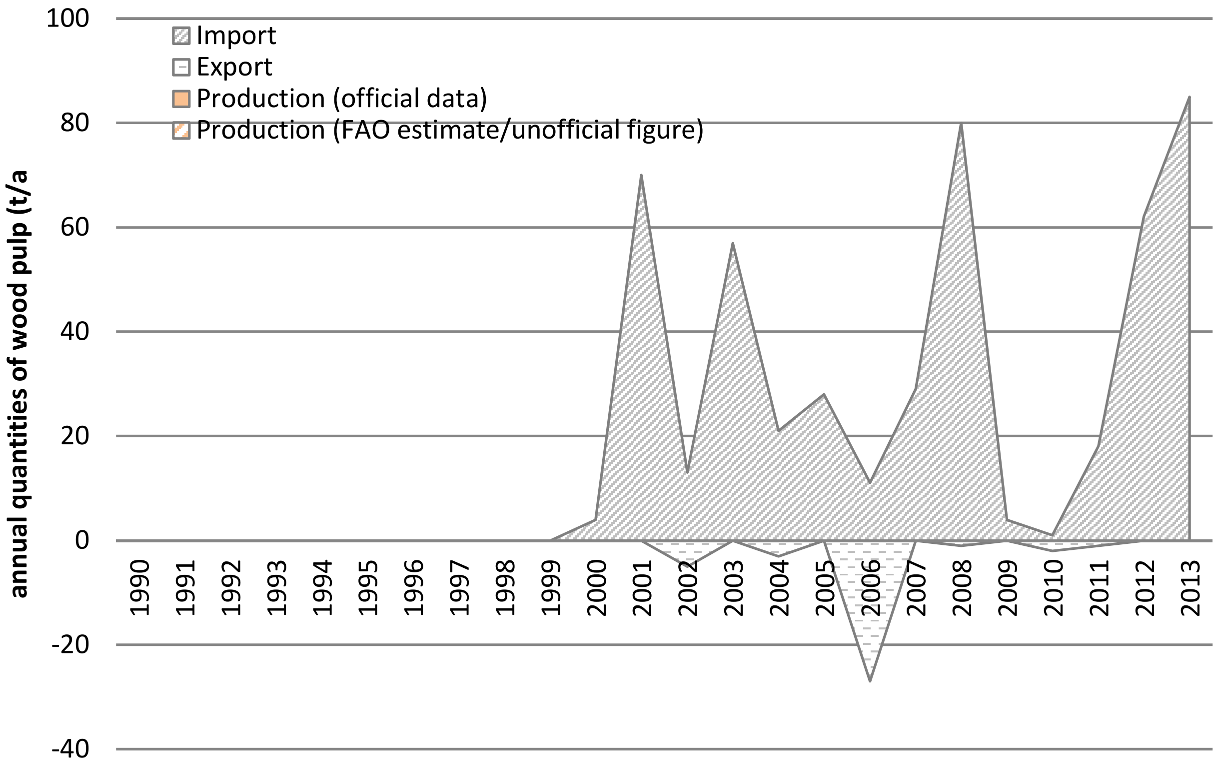
"Fibrous material prepared from pulpwood, wood chips, particles, residues or recovered paper by mechanical and/or chemical process for further manufacture into paper, paperboard, fibreboard or other cellulose products. In the production and trade statistics, it represents the sum of: mechanical wood pulp; semi-chemical wood pulp; chemical wood pulp; and dissolving wood pulp. It is reported in metric tons air-dry weight (i.e. with a 10% moisture content)" (FAO, 2015)

A detailed analysis of the quantities of wood pulp produced, imported and exported is required in order to estimate the annual fraction of the feedstock coming from domestic harvest for the HWP category paper and paperboard. The share of domestically produced wood pulp is calculated with the following equation (Hirashi, et al., 2014)

$$f_{PULP}(i) = \frac{PULP_P(i) - PULP_{EX}(i)}{PULP_P(i) + PULP_{IM}(i) - PULP_{EX}(i)} \quad \textbf{(Equation 6-2)}$$

$f_{PULP}(i)$ = share of domestically produced wood pulp

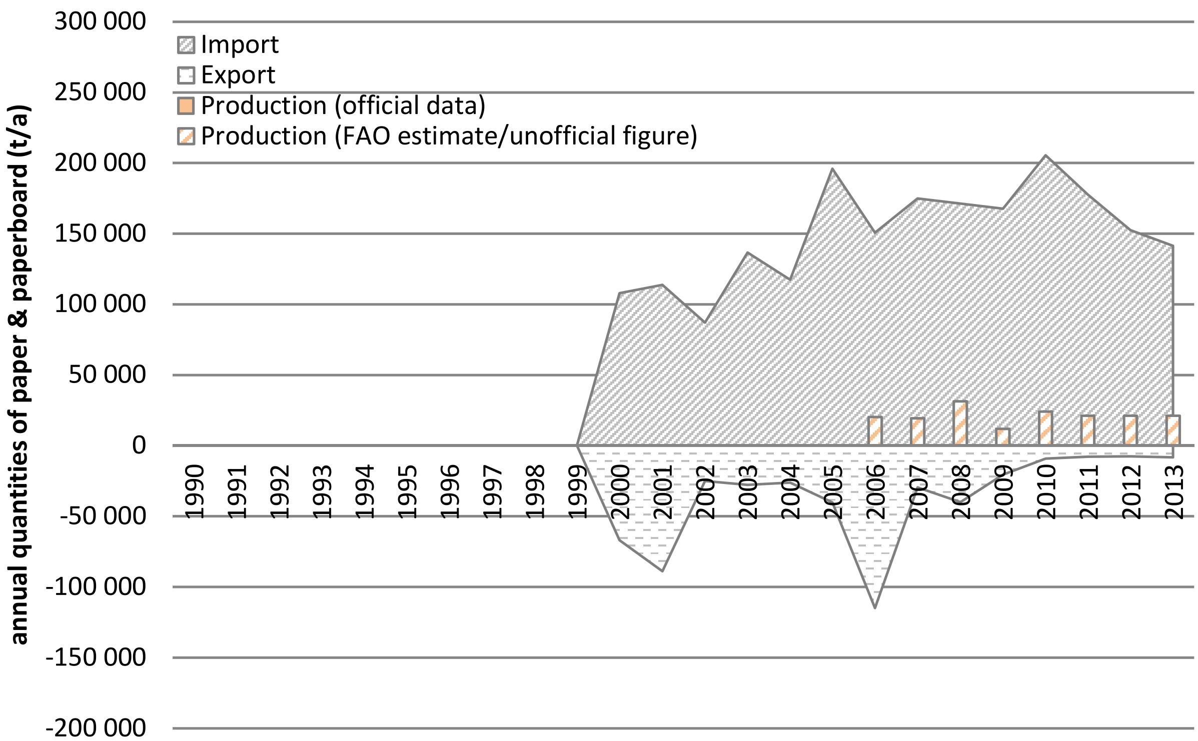
Figure 6-25: import, export and production of wood pulp in Luxembourg (origin: FAO)



All the data available for woodpulp has been taken from the FAO database. Official data on production is available for the years 2007 – 2013 and reported to be 0. The data as it is at this moment in time leads to estimate the annual fraction of the feedstock coming from domestic harvest for the HWP category paper and paperboard as 0.

6.9.6 Activity data: production, imports and exports of paper and paperboard

Figure 6-26 import, export and production of paper and paperboard (origin: FAO)



Production of paper and paperboard is only marginal in Luxembourg and the related carbon pool is thus insignificant.

6.9.7 Conclusion

The wood industry in Luxembourg is dominated by one major producer of OSB and fiberboard panels and as a consequence the carbon pool of wood-based panels is by far the most relevant carbon pool of HWP. This report has shown that the assessment of the carbon pool originating from harvested wood products is however based on a highly disperse dataset. The Tier 2 method based on the sole use of data originating from the FAO database is almost unusable for Luxembourg.

According to GPG 2006 "the HWP contribution can be reported as zero if the inventory compiler judges that the annual change in carbon in HWP stocks is insignificant. Either the stocks in the country (Variable +1A + Variable +1B), or the annual change in carbon in HWP stocks originating from wood harvest in the country (including exported HWP) (variable 2A + variable 2B9 may be considered. The term 'insignificant' in this context means that the annual change in carbon in HWP stocks, using one of the measures of carbon change above, is less than the size of any key category." In order to calculate if the annual change in carbon in HWP stocks is insignificant detailed data would have to be available on the production of wood-based products originating from domestic harvest. This data is however not available and this condition cannot be verified.

According to 2013 Revised Guidelines: "It is good practice to apply the Tier 1 method as outlined in this section (i.e. reporting no net-emissions from HWP) only in the case that transparent and verifiable activity data for the default categories sawnwood, wood-based panels and paper and paperboard as outlined in section 2.8.1.1 are not available." The previous sections have clearly highlighted how unreliable the data from the FAO is for Luxembourg and subsequently **all emissions from the HWP pool will be reported as instantaneous oxidation**.

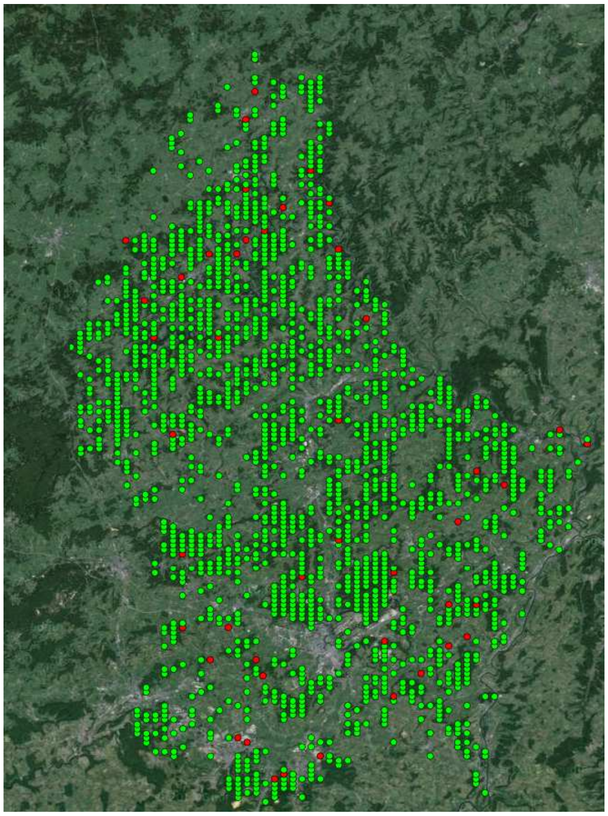
6.10 Category-specific QA/QC and verification

Processing of land use maps is verified as follows:

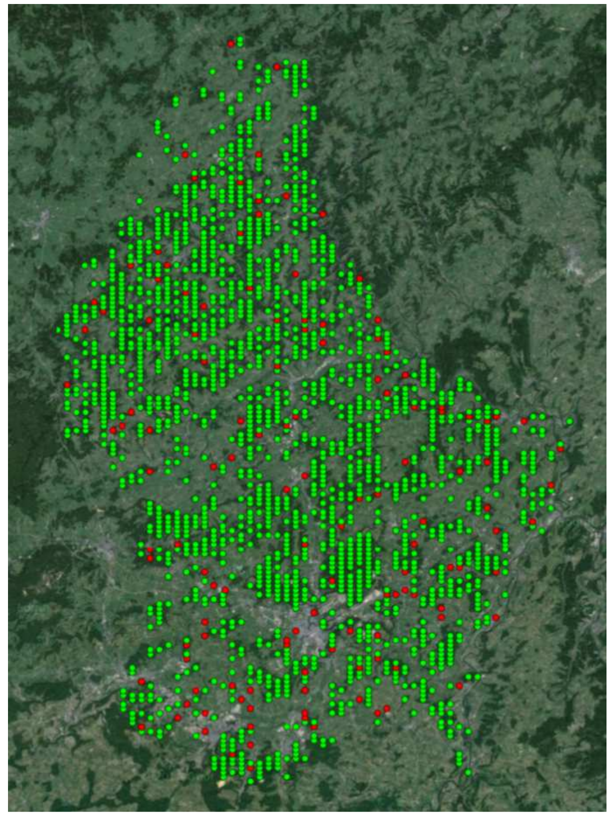
- field surveys were used during the establishment of the original land use maps in 1989, 2000 and 2007 (see section 1.1.3.1). This method allowed, for example, a better differentiation between permanent cropland (*e.g.* walnut and chestnut trees plantations) from other broad leaf trees in forests.
- digital sources: For the quality check of the land use map LU12 and LUC between LU07 and LU12, other digital sources were used such as digital aerial orthophotos and LUCAS 2012 data / photographs, provided by Eurostat. The quality assessment consisted in controlling 2200 randomly sampled points (200 per class) resulting in an overall accuracy of 98.01%.

Comparison with total forest area generated by land use maps and forest inventory:

Figure 6-27 – Comparison of NFI grid definition points to LUC analysis



Red points are areas defined as forest in the NFI but not in the LUC anaylsis (total: 45)



Red points are defined as forest in the in the LUC anaylsis but not in the forest inventory (total: 114)

In order to compare the results of total forest area obtained via land use maps (based on aerial and satellite pictures) and the total forest area obtained via the NFI a detailed analysis has been conducted via a GIS program. For this exercise the layer of grid points of the NFI have been put in comparison to the latest land use map from 2012.

According to the data generated by the LUC analysis the forest area in the year 2012 was 96 107 ha compared to 92 150 ha estimated by the NFI. The difference of 3 957 ha (4%) is very small and can most likely be explained by the two different methodologies employed. (Note: the total forest area according to the FAOSTAT (88 700 ha) does not include "other wooded areas" and "grove area" and is hence smaller than the total forest area estimated by the NFI). Nevertheless a comparison between the two set of results was conducted in order to rule out any major definition issues:

As can be seen in Figure 1-27 the difference in numbers of red points is in line with the difference in total surface area (114-45 = 69 -> 3 450 ha (according to NFI calculation with 50 ha/point), compared to 3 957 ha calculated above).

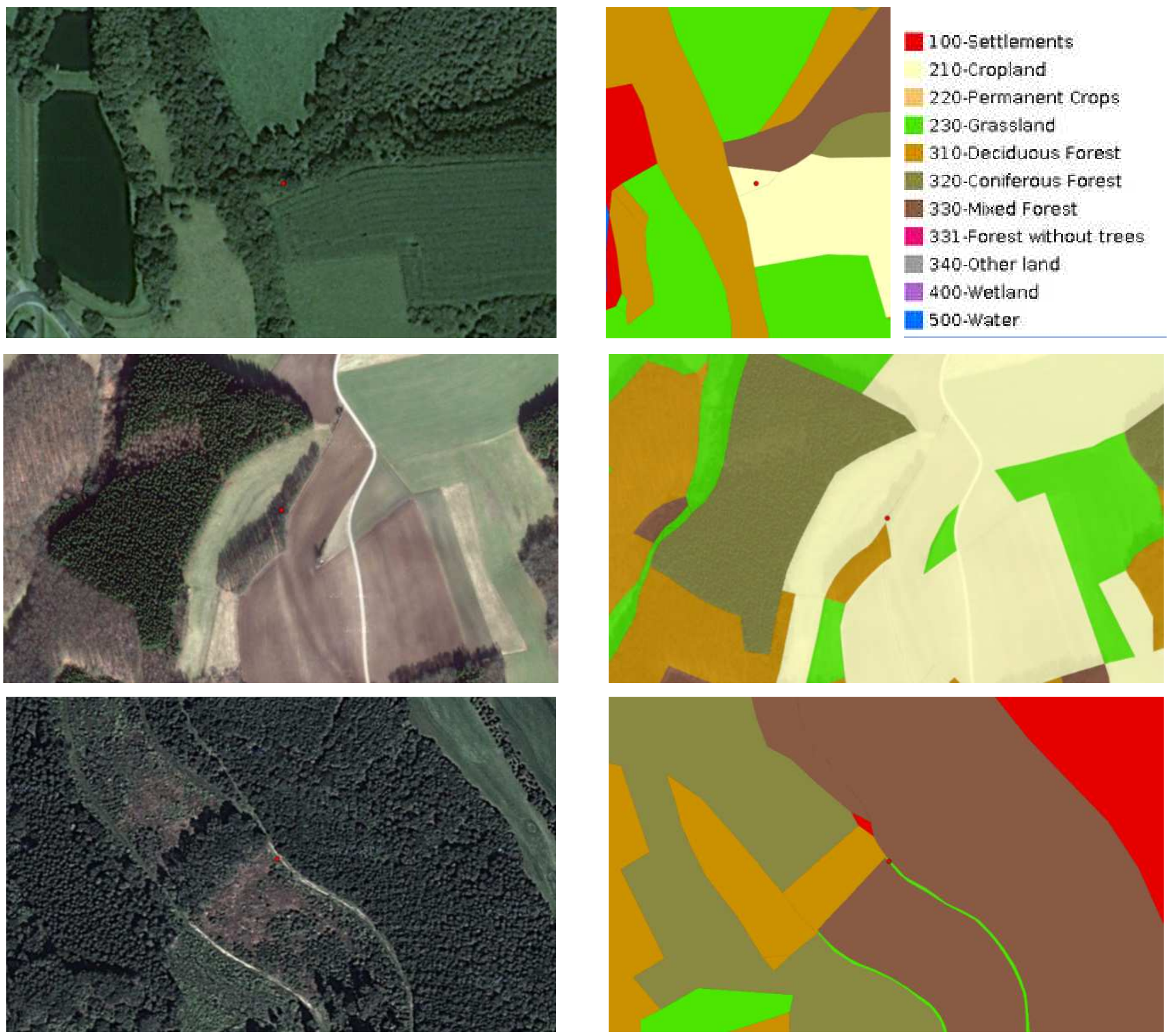
The figures here below show a sample of red points in order to highlight the type of differences or errors between both methodologies.

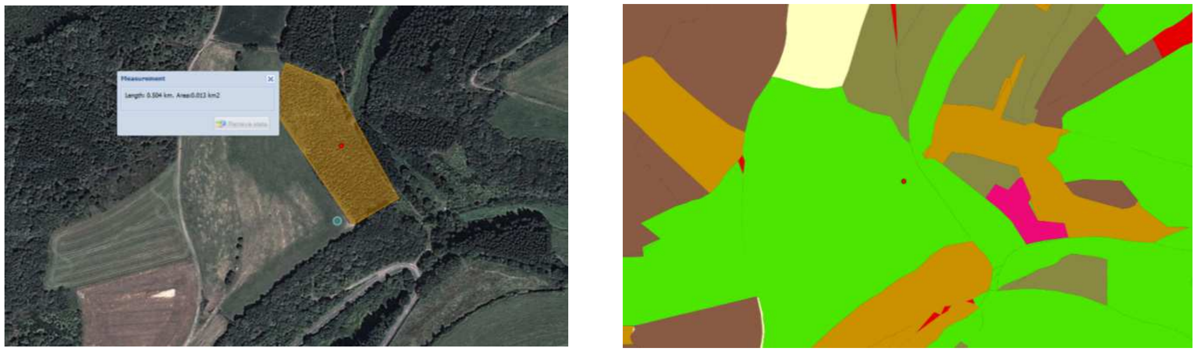
Figure 6-28 – points defined as forest in NFI but not in LUC method

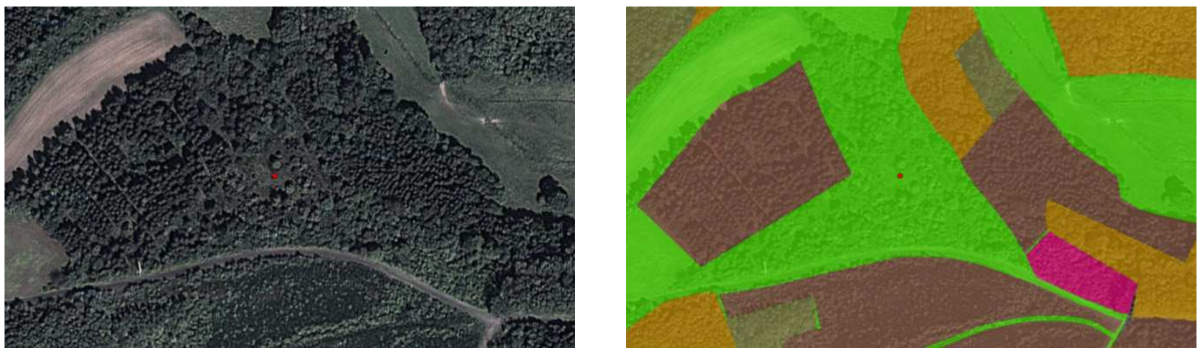
1

2

3

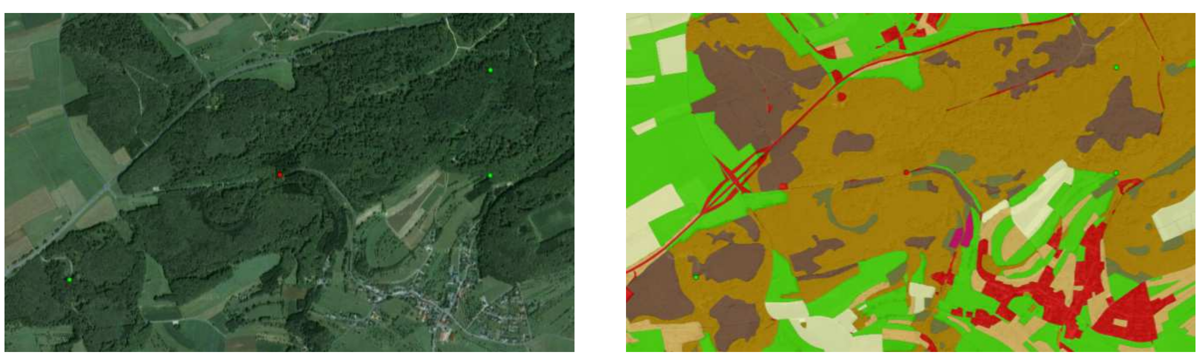


4 

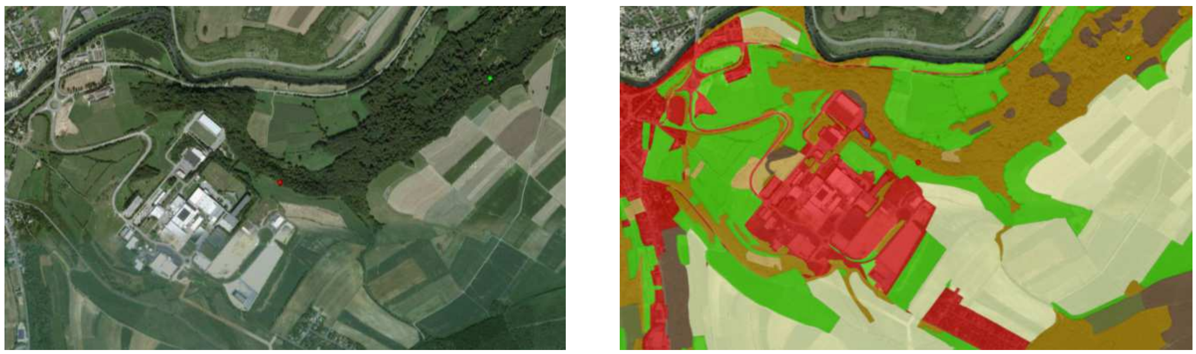
5 

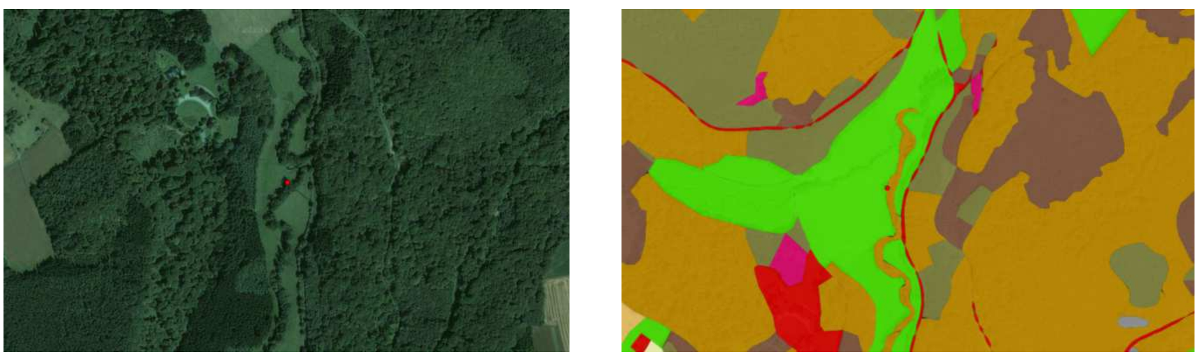
Figures 1, 2 and 3 show typical points that might not be defined as forest area in the LUC methodology but are limited to a very small area surrounded by forest and have almost no influence on the results. Pictures 4-5 show examples with higher influence on the results (the errors in these cases are due to the methodology of the 2007/2012 analysis which kept the underlying geometry of the 2007). Nevertheless the generated errors are small (13 ha in the case of example in figure 4).

Figure 6-29 – points defined as forest in LUC but not in NFI

6 

7 

8 

9 

10 

Pictures 6-8 show typical points that are situated at the border of a forest and are not considered as forest in the NFI. In those examples the precision of the results from the LUC analysis are superior to those of the NFI. Figure 9-10 show how the LUC methodology takes into account often smaller patches of forest which can lead to higher areas of land use changes as those forest areas are more likely to get cut down or to be planted (in the case of abandoned land for example).

The match between the two methodologies can be seen as satisfactory and does not highlight any need for further amendments to the LUC method used for the calculation of the LULUCF inventory.

6.11 Category-specific recalculations including changes made in response to the review process

Table 1-35 presents the main revisions and recalculations done since submission 2014v1.4 relevant to CRF Sector 4.

Table 6-35 – Changes in GHG inventories: submissions 2016v1 and 2017v1.2

GHG source & sink category	Revisions 2016v1➔ 2017v1.2	Type of revision
4 - LULUCF areas	Data of land use changes between forestland and wetland for the time series between 1990-1999 were revised	Revised AD
4 - LULUCF areas	Data of land use changes between perennial cropland and grassland for the time series between 1990-1999 were revised	Revised AD
4 - LULUCF areas	Data of land use changes between grassland and cropland were extracted from the LPIS database for the years 2009-2015.	Revised AD
4 – LULUCF	Calculation of indirect N2O emissions for Nitrogen leaching related to direct N2O emissions from nitrogen mineralisation associated with loss of soil organic matter resulting from change of land.	Calculation of N2O emission LU-4-2017-0002
4 – LULUCF	A comprehensive uncertainty and time series consistency analysis was carried out for the LULUCF sector.	Revision of uncertainties ARR 2014, §60
4 - LULUCF	N2O emissions (direct and leached emission) associated with loss of soil carbon were calculated for all land use changes (previously only those associated with cropland were calculated).	LU-3D-2016-0001

6.11.1 Land-use definitions and the classification systems used and their correspondence to the LULUCF categories

The OBS89, OBS99 and OBS07 land use maps are the main data providers for the greenhouse gas reporting of IPCC category other land. The selected parameters defining other land are:

Land Use Class	Definition
Other land	This category includes bare soil, rock, ice, and all unmanaged land areas that do not fall into any of the other five categories. It allows the total of identified land areas to match the national area, where data are available.

The other land area in correspondence to the LULUCF category comprises the following subcategories:

- Rocks and screes
- Land with no vegetation,

- Abandoned quarries.

6.12 Category-specific planned improvements

Taking into account the potential contribution of identified improvements in the total GHG emissions and the corresponding resources needed to make these improvements effective, developments presented Table 1-36 will be explored.

Table 6-36 – Planned improvements for IPCC Sector 4 – LULUCF

GHG source & sink category	Planned improvement
4A	Luxembourg plans to revise its OBS maps by 2018-2019

7 Waste (CRF Sector 5)

7.1 Sector Overview

This chapter includes information on and description of methodologies used for estimating GHG emissions, as well as references to activity data and emission factors reported under CRF Sector *5 – Waste* for the period 1990 to 2015. Emissions from this sector comprise emissions for the three main IPCC categories: *5A - Solid Waste Disposal*, *5B - Biological Treatment of Solid Waste* and *5D – Wastewater Treatment and Discharge*.

GHG emissions related to *5C – Incineration and Open Burning of Waste* are allocated to IPCC subcategory *1A1a – Fuel Combustion Activities – Energy Industries – Public Electricity and Heat Production* (see Section 3.2.6) since energy is recovered and injected into the public electricity network from waste burned in the sole incinerator of the country.

7.1.1 Emission Trends

As shown in Figure 7-1 and Table 7–1, that provide a quick overview on *Waste* and *Wastewater Treatment and Discharge* related emission trends between 1990 and 2015, and Figure 7-2 depicting the shares of each IPCC category under CRF Sector *5* for both the years 1990 and 2015, total waste related GHG emissions have decreased by 16.94% from 1990 to 2015, and by 3.85% between 2014 and 2015.

Figure 7-1 – GHG Emission Trends for CRF Sector 5 – Waste: 1990-2015

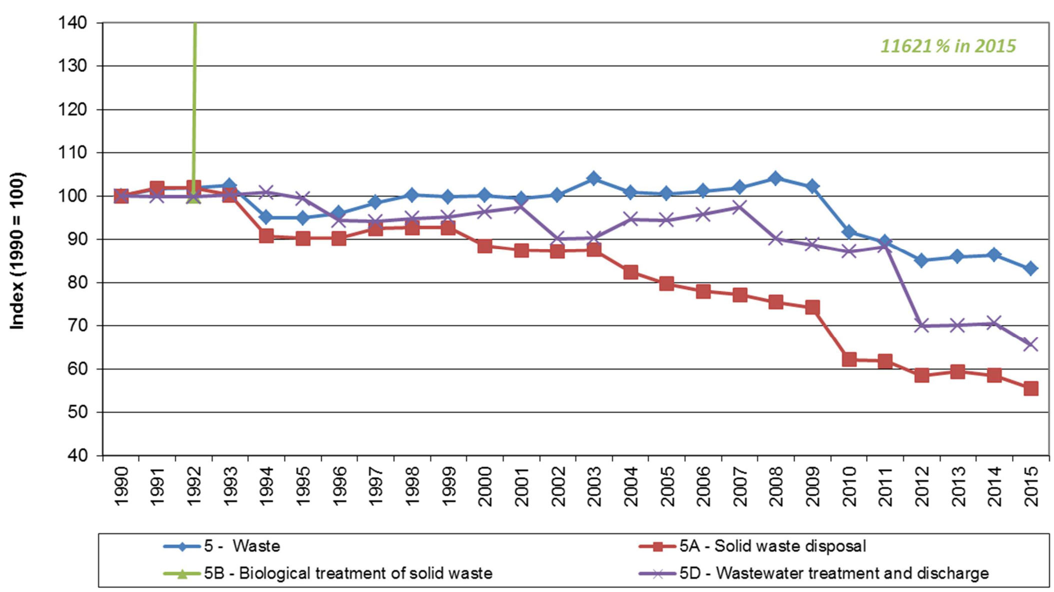
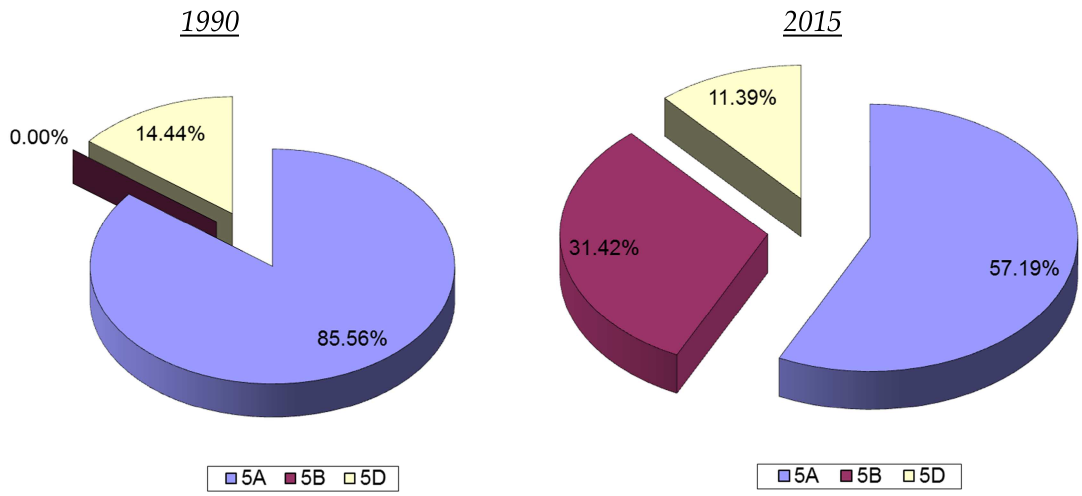


Figure 7-2 – IPCC Categories Weights for CRF Sector *5* – *Waste*: 1990 and 2015



The above mentioned trend evolution was mainly driven by the fact that, for IPCC category ***5A – Solid Waste Disposal***, methane emissions have been reduced by 44.48% between 1990 and 2015 due to:

- an increase in aerobic treatment[131] before landfilling;
- a decrease in the quantity of waste being landfilled, notably through the development of recycling schemes, and the expansion of both the numbers of and the various waste categories collected by recycling centres;
- the recent installation of methane recovery systems at waste dumping sites.

No CO_2 emissions derived from non-biological or inorganic waste sources have been identified so far from waste disposal on land.

For category ***5B – Biological Treatment of Solid Waste***, unlike IPCC category *5A*, an increase of emissions is recorded for the years 1992 to 2015 for *5B1*. With regard to compost production as well as aerobic treatment of solid waste, these activities have only started on an "industrial scale" in the early 1990s. The accelerated development of compost production from 1993-2003 explains the very high, and therefore not really exploitable, percentage growths observed for both CH_4 and N_2O. Since 2003, compost production activity has more or less stabilized (Section 7.3). In addition, as Luxembourg has committed itself under the Kyoto Protocol to an increased

131 Aerobic treatment refers to the cold treatment at SIGRE, and the mechanical-biological treatment at SIDEC.

share of electricity produced from renewable sources, fugitive CH_4 emissions from the use of biomass in anaerobic digesters in *5B2* have accumulated (since 1992).

For this analysis, IPCC category ***5C – Incineration and Open Burning of Waste*** is excluded since, as indicated above, it is entirely accounted for under IPCC subcategory *1A1a – Fuel Combustion Activities – Energy Industries – Public Electricity and Heat Production*. Consequently, IE is reported for this category in CRF Table *5C* (Table 7–2).

Table 7-1 – GHG Emission Trends in CO_2e for CRF Sector *5* – Waste: 1990-2015

5 - Waste

CO_2 eq emissions (Gg) by source & sink category

Year	*5A - Solid Waste Disposal*				*5B - Biological Treatment of Solid Waste*				*5D - Wastewater Treatment and Discharge*				*5 - Waste*			
	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O
1990	95.76	*NA*	*95.76*	*NA*	0.00	*NO*	*NO*	*NO*	16.16	*NA*	*7.30*	*8.86*	111.92	*NA*	*103.07*	*8.86*
1991	97.54	*NA*	*97.54*	*NA*	0.00	*NO*	*NO*	*NO*	16.15	*NA*	*7.12*	*9.03*	113.69	*NA*	*104.66*	*9.03*
1992	97.56	*NA*	*97.56*	*NA*	0.25	*NO*	*0.25*	*0.00*	16.13	*NA*	*6.94*	*9.20*	113.95	*NA*	*104.75*	*9.20*
1993	95.90	*NA*	*95.90*	*NA*	2.49	*NO*	*1.56*	*0.93*	16.21	*NA*	*6.76*	*9.46*	114.60	*NA*	*104.21*	*10.39*
1994	86.95	*NA*	*86.95*	*NA*	3.12	*NO*	*1.93*	*1.20*	16.30	*NA*	*6.57*	*9.73*	106.38	*NA*	*95.45*	*10.92*
1995	86.45	*NA*	*86.45*	*NA*	3.74	*NO*	*2.30*	*1.44*	16.07	*NA*	*6.39*	*9.68*	106.25	*NA*	*95.14*	*11.12*
1996	86.45	*NA*	*86.45*	*NA*	5.79	*NO*	*3.49*	*2.30*	15.25	*NA*	*6.17*	*9.08*	107.48	*NA*	*96.11*	*11.37*
1997	88.58	*NA*	*88.58*	*NA*	6.42	*NO*	*3.84*	*2.59*	15.21	*NA*	*5.95*	*9.26*	110.21	*NA*	*98.37*	*11.84*
1998	88.76	*NA*	*88.76*	*NA*	8.08	*NO*	*4.79*	*3.29*	15.32	*NA*	*5.73*	*9.59*	112.16	*NA*	*99.27*	*12.89*
1999	88.82	*NA*	*88.82*	*NA*	7.47	*NO*	*4.42*	*3.05*	15.37	*NA*	*5.51*	*9.86*	111.66	*NA*	*98.74*	*12.92*
2000	84.76	*NA*	*84.76*	*NA*	11.66	*NO*	*7.07*	*4.59*	15.57	*NA*	*5.28*	*10.29*	111.98	*NA*	*97.11*	*14.87*
2001	83.72	*NA*	*83.72*	*NA*	11.82	*NO*	*7.38*	*4.44*	15.75	*NA*	*5.13*	*10.61*	111.29	*NA*	*96.24*	*15.05*
2002	83.53	*NA*	*83.53*	*NA*	13.99	*NO*	*8.70*	*5.29*	14.58	*NA*	*4.98*	*9.60*	112.10	*NA*	*97.21*	*14.89*
2003	83.86	*NA*	*83.86*	*NA*	17.92	*NO*	*11.36*	*6.57*	14.59	*NA*	*4.83*	*9.76*	116.36	*NA*	*100.04*	*16.32*
2004	78.96	*NA*	*78.96*	*NA*	18.51	*NO*	*12.02*	*6.50*	15.30	*NA*	*4.68*	*10.62*	112.77	*NA*	*95.65*	*17.12*
2005	76.26	*NA*	*76.26*	*NA*	20.90	*NO*	*13.82*	*7.08*	15.26	*NA*	*4.49*	*10.77*	112.43	*NA*	*94.58*	*17.85*
2006	74.63	*NA*	*74.63*	*NA*	23.07	*NO*	*15.41*	*7.66*	15.47	*NA*	*4.43*	*11.04*	113.17	*NA*	*94.47*	*18.71*
2007	73.85	*NA*	*73.85*	*NA*	24.43	*NO*	*16.44*	*7.99*	15.74	*NA*	*4.41*	*11.33*	114.02	*NA*	*94.70*	*19.32*
2008	72.19	*NA*	*72.19*	*NA*	29.67	*NO*	*19.93*	*9.74*	14.58	*NA*	*4.11*	*10.48*	116.45	*NA*	*96.23*	*20.22*
2009	71.12	*NA*	*71.12*	*NA*	28.86	*NO*	*20.02*	*8.83*	14.35	*NA*	*3.77*	*10.58*	114.33	*NA*	*94.92*	*19.41*
2010	59.47	*NA*	*59.47*	*NA*	29.12	*NO*	*20.34*	*8.79*	14.09	*NA*	*3.69*	*10.40*	102.68	*NA*	*83.49*	*19.19*
2011	59.16	*NA*	*59.16*	*NA*	26.57	*NO*	*18.81*	*7.76*	14.29	*NA*	*4.13*	*10.15*	100.02	*NA*	*82.11*	*17.91*
2012	56.02	*NA*	*56.02*	*NA*	27.86	*NO*	*19.72*	*8.14*	11.31	*NA*	*4.06*	*7.25*	95.19	*NA*	*79.80*	*15.39*
2013	56.89	*NA*	*56.89*	*NA*	27.96	*NO*	*19.70*	*8.26*	11.33	*NA*	*3.93*	*7.39*	96.18	*NA*	*80.52*	*15.66*
2014	56.02	*NA*	*56.02*	*NA*	29.26	*NO*	*20.70*	*8.56*	11.41	*NA*	*3.85*	*7.57*	96.69	*NA*	*80.56*	*16.13*
2015	53.17	*NA*	*53.17*	*NA*	29.21	*NO*	*20.75*	*8.47*	10.59	*NA*	*3.50*	*7.09*	92.97	*NA*	*77.41*	*15.56*
Trend 1990-2015	*-44.48%*	*NA*	*-44.48%*	*NA*	*NA*	*NA*	*NA*	*NA*	*-34.47%*	*NA*	*-52.05%*	*-19.98%*	*-16.94%*	*NA*	*-24.89%*	*75.60%*
Trend 2014-2015	*-5.09%*	*NA*	*-5.09%*	*NA*	*-0.15%*	*NA*	*0.24%*	*-1.10%*	*-7.22%*	*NA*	*-9.01%*	*-6.31%*	*-3.85%*	*NA*	*-3.91%*	*-3.54%*

Notes: CH_4 emissions are converted in CO_2e by multiplying the emissions by 25, *i.e.* the global warming potential (*GWP*) value for methane based on the effects of GHG over a 100-year time horizon. N_2O emissions are converted in CO_2e by multiplying the emissions by 298, *i.e.* the global warming potential (*GWP*) value for nitrous oxide based on the effects of GHG over a 100-year time horizon (Table 2.14, IPCC Fourth Assessment Report: Climate Change 2007: Working Group I: The Physical Science Basis).

For IPCC category ***5D – Wastewater Treatment and Discharge***, emissions decreased by 34.47% in 2015 compared to the base year 1990, and by 7.22% compared to 2014. Wastewater treatment plant (WWTP) capacities expressed in population-equivalents have steadily grown (Section 7.6, Table 7–24) over the period 1990 to 2015[132], whereas nitrous oxide emissions (Table 7–1) decreased by 19.98%. With regard to wastewater treatment, technical changes therefore have an unquestionable role, as the evolution of methane emissions (-52.05% from 1990 to 2015) confirms.

7.1.2 Completeness

Table 7-2 provides more details on the IPCC categories included under CRF Sector *5*, in which emissions are not occurring for activities or processes (*NO*), emissions do not result from activities in the given source category (*NA*), emissions are considered negligible (*NE*) and/or emissions that are included elsewhere (*IE*) in the inventory.

Table 7-2 – Overview of CRF *Sector 5 – Waste* Subcategories: Status of Emission Estimates for CO_2, CH_4 and N_2O

GHG source & sink category	Description	Status		
		CO_2	CH_4	N_2O
***5A* - Solid Waste Disposal**				
5A1	Managed waste disposal sites	NA	X	
5A2	Unmanaged waste disposal sites	NO	NO	
5A3	Uncategorized waste disposal sites	NO	NO	
***5B* - Biological Treatment of Solid Waste**				
5B1	Composting		X (1993-2015)	X (1993-2015)
5B1	Pre-treatment of solid waste		X (1993-2015)	X (1993-2015)
5B2	Anaerobic digestion at biogas facilities		X (1992-2015)	NE
***5C* - Incineration and Open Burning of Waste**				
5C1	Waste incineration	IE *	IE *	IE *
5C2	Open burning of waste	NO	NO	NO
***5D* - Wastewater Treatment and Discharge**				
5D1	Domestic wastewater		X	X

132 This increase is notably explained by *(i)* the significant population growth between 1990 and 2015, and *(ii)* the increasing number of commuters who are crossing the border each working day (Section 2.1). Percentage growths recorded for these two variables are, as well, largely above the one estimated for N_2O emissions from WWTP.

GHG source & sink category	Description	Status		
		CO_2	CH_4	N_2O
5D2	Industrial wastewater		NO	X
5D3	Other		NO	NO

Note: X indicates that emissions from this subcategory have been estimated.

The grey shaded cells are those also shaded in the CRF tables (AD has not been specified, or cells are blocked for editing).

* = Waste incineration is recorded under CRF subcategory *1A1a* since electricity is produced from incinerated municipal waste residues.

7.1.3 Luxembourg's Waste Generation and Management System

The common basis for activity data to estimate emissions from IPCC categories *5A – Solid Waste*, *5B – Biological Treatment of Solid Waste*, and *5C – Incineration and Open Burning of Waste* is the generation of **municipal solid waste** (MSW). MSW consists of waste collected from households, as well as refuses generated by small industrial enterprises, retail shops and services (private or institutional). In other words, MSW corresponds to the totality of waste collected by municipalities [133] (Total MSW).

According to the modified Luxembourgish Law of March 21, 2012 [134], the collection of MSW falls within the competence of municipalities that joined to **municipal waste management syndicates**. These inter-municipal syndicates for the management of household and similar to household waste include:

- SIDA, for the municipalities of the regions Wiltz and others of the North of the country;
- SIDEC, for the municipalities of the regions Diekirch, Ettelbruck and Colmar-Berg;
- SIDOR, for the municipalities of the districts Luxembourg, Esch-sur-Alzette and Capellen;
- SIGRE, for the municipalities of the regions Grevenmacher, Remich and Echternach.

Unmanaged Landfill Sites

133 For details on municipal waste collection, see:
http://www.environnement.public.lu/dechets/statistiques_indicateurs/LUXUS_Daten/index.html (in German)
http://www.environnement.public.lu/dechets/statistiques_indicateurs/index.html, line "*Activité des parcs à conteneurs (recycling centres)*" (in French).

134 Loi modifiée du 21 mars 2012 relative à la gestion des déchets, et modifiant la loi du 31 mai 1999 portant institution d'un fonds pour la protection de l'environnement; la loi du 25 mars 2005 relative au fonctionnement et au financement de l'action SuperDrecksKëscht; la loi du 19 décembre 2008 a) relative aux piles et accumulateurs ainsi qu'aux déchets de piles et d'accumulateurs; b) modifiant la loi modifiée du 17 juin 1994 relative à la prévention et à la gestion des déchets; la loi du 24 mai 2011 relative aux services dans le marché intérieur.
http://www.legilux.public.lu/leg/a/archives/2012/0060/2012A0670A.html

Before the syndicates installed the managed solid waste disposal sites (SWDS), the waste was dumped to local unmanaged dumping sites within the municipalities. In 1980, the first law on waste was voted in Luxembourg. Between 1981 and 1982, around 110 permits were issued for unmanaged landfill sites. When the new waste legislation came into force in 1994, all private and municipal unmanaged landfills had to be closed. The areas were cleaned, planted and designed to fit into the landscape. A cadaster was set up, with all landfill sites that could be contaminated.

Since 1994, inspections were systematically performed by the Environment Agency at a total of 616 former landfills. The Environment Agency oversaw the work that lasted until 2005. No abnormal behavior of these closed sites has been detected and no corrective actions have been required.

As an example for the successful closing procedure of former landfill sites is the dumping site in Bettembourg next to the leisure park "*Parc Merveilleux*", visited by lots of families during the summer months. About 500 000 m^3 MSW had been deposited at this site in the 1980s, and after closure, the site was equipped with a drainage system and covered with a one meter thick layer of earth. Specific analysis showed that the anaerobic fermentation process was finished, and no methane emissions stemming from the site could be detected. Hence, it was decided that in the future, these sites could be annexed to the leisure park, to host larger compounds for animals (such as a deer park).

The controlled landfills of SIDEC and SIGRE opened in 1972 and 1979, respectively. Table 7-3 summarizes the situation for each waste management syndicate.

Table 7-3 – Municipal Solid Waste Management in Luxembourg

Syndicate	Waste Elimination Scheme	Operating Years with Regard to the GHG Inventory
SIDA	Landfill	till 1993
SIDEC	Landfill	1972-2014
	+ Methane recovery system	*2002-2015*
	+ Biological treatment	*2007-2015*
SIDOR	Incineration	1976-2015
SIGRE	Landfill	1979-2015
	+ Aerobic treatment	*1993-2015*
	+ Methane recovery system	*2000-2015*

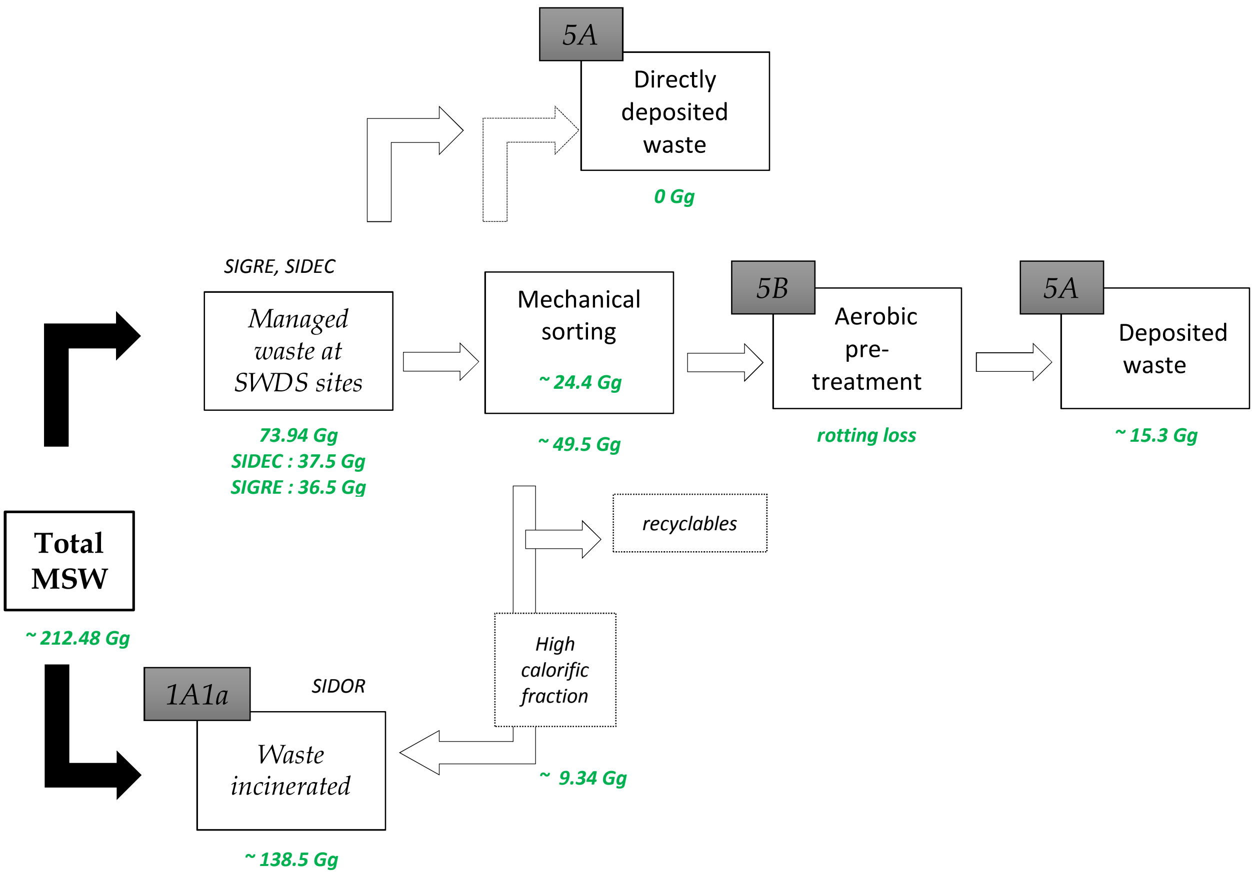
Source: .... Environment Agency.

......................SIDEC (www.sidec.lu), SIDOR (http://sidor.lu), and SIGRE (www.sigre.lu)

The waste management syndicates, listed in Table 7-3, existed in 1990 and managed their own dumping or incineration site. In 1994, however, SIDA was merged with SIDEC and its dumping site closed down. Till 2015, there have been two controlled landfill sites (one managed by SIDEC and one managed by SIGRE) and one incinerator (managed by SIDOR) for the whole country of Luxembourg. In 2015, the syndicates have decided to use only one controlled landfill site in Muertendall, managed by SIGRE [135].

A **methane recovery system** has been in operation at the SIGRE site since 2000, and at the SIDEC site since 2002. The **aerobic treatment** in heaps has been performed at SIGRE since 1993. Also, pre-treatment of solid waste prior landfilling of waste in tunnels has been fully operational since 2007 at SIDEC.

Figure 7-3 – Waste Flow in Luxembourg for the year 2015



The total municipal solid waste (Total MSW, municipal waste from households and similar household waste), accounted for in the inventory (Figure 7-3), is – upon collection - either

- **partly** – directly [136] or indirectly after treatment - **landfilled** (*i.e.* solid waste to be accounted for under IPCC category *5A*),

135 http://www.beaufort.lu/Collaboration_DE.pdf?FileID=publications%2Fcollaboration_de.pdf

- **partly incinerated** (*i.e.* solid waste to be accounted for under IPCC category *1A1a* as energy is recovered from incineration), or
- **partly recycled or recovered** (Box "*Recycling Rates for Packaging Waste*").

Recycling Rates for Packaging Waste

According to Article 10(1) on valorisation and recycling of the Grand-Ducal Regulation of 22 February 2006[137], the following recycling rates must have been achieved throughout the territory

(a) by 30 June 2001 at the latest, 55% by weight of the packaging waste shall be recovered;

(b) by 31 December 2008 at the latest, 65% by weight of packaging waste shall be recovered or incinerated in waste incineration plants with energy recovery;

(c) by 30 June 2001 at the latest, within the overall objective, 45% by weight of all packing materials;

(d) by 31 December 2008 at the latest, 60% by weight of the packaging waste shall be recycled with the following minimum recycling targets for the materials contained in the packaging waste:

- 60% by weight for glass,
- 60% by weight for paper and paperboard,
- 50% by weight for metals,
- 22.5% by weight for plastics, exclusively counting materials that are recycled as plastics,
- 15% by weight for wood.

As a consequence, local authorities have organized door-to-door collections of selected refuses (paper and cardboard, packaging, garden waste, *etc.*), recycling centres and/or on-street specific waste containers in which the selected waste can be deposited.

7.1.4 Legislation

The most important legislative and regulatory measures, which have reduced the waste-related emissions from **Luxembourg,** are included in the

(i) EU Waste Framework Directive 2008/98/EC,

(ii) Landfill Directive 1999/31/EC,

(iii) Waste Incineration Directive 2000/76/EC, and

136 Direct landfilling of waste concerns waste with (dotted arrow in Figure 7-3) or without mechanical sorting. Indirect landfilling of waste concerns waste that is pre-treated.

137 Règlement grand-ducal du 22 février 2006 modifiant le règlement grand-ducal modifié du 31 octobre 1998 portant application de la directive 94/62/CE du Parlement Européen et du Conseil du 20 décembre 1994 relative aux emballages et aux déchets d'emballages. http://legilux.public.lu/eli/etat/leg/rgd/2006/02/22/n1/jo

(iv) *Loi du 18 décembre 2015 modifiant la loi modifiée du 21 mars 2012 relative aux déchets*, and *Règlement grand-ducal du 18 décembre 2015 relatif aux avertissements taxés déterminant les modalités d'application de l'avertissement taxé et établissant un catalogue des contraventions soumises à l'avertissement taxé prévu par la loi modifiée du 21 mars 2012 relative aux déchets*.

The **Waste Framework Directive** mandates waste management as a priority to prevention (non-waste), re-use, recycling and recovery. The latter Directive, which also has introduced the "*polluter pays principle*", has been transposed on the national level by the Luxembourgish Law of March 21, 2012 [138].

The modern requirements for disposal sites in order to reduce methane generation of the **Landfill Directive** have been transposed into national legislation through the Grand-Ducal Regulation of February 24, 2003 [139], subsequently amended and rectified by the Grand-Ducal Regulation of February 17, 2006 [140].

The aim of the **Waste Incineration Directive**, transposed by the Grand-Ducal Regulation of May 9, 2014[141], is to prevent or to reduce emissions caused by the incineration of waste. This is to be achieved through the application of operational conditions, technical requirements, and emission limit values for incineration plants within the EU.

Article 42 of the national law of **18 December 2015**[142] states that the abandonment, dumping or uncontrolled management of waste is prohibited. This statement includes the prohibition of

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138 *Loi modifiée du 21 mars 2012 relative à la gestion des déchets, et modifiant la loi du 31 mai 1999 portant institution d'un fonds pour la protection de l'environnement; la loi du 25 mars 2005 relative au fonctionnement et au financement de l'action SuperDrecksKëscht; la loi du 19 décembre 2008 a) relative aux piles et accumulateurs ainsi qu'aux déchets de piles et d'accumulateurs; b) modifiant la loi modifiée du 17 juin 1994 relative à la prévention et à la gestion des déchets; la loi du 24 mai 2011 relative aux services dans le marché intérieur.*
http://www.legilux.public.lu/leg/a/archives/2012/0060/2012A0670A.html

139 Règlement grand-ducal du 24 février 2003 concernant la mise en décharge des déchets, http://www.legilux.public.lu/leg/a/archives/2003/0034/2003A05461.html

140 Règlement grand-ducal du 17 février 2006 modifiant le règlement grand-ducal du 24 février 2003 concernant la mise en décharge des déchets, http://www.legilux.public.lu/leg/a/archives/2006/0036/2006A0696A.html
http://www.legilux.public.lu/leg/a/archives/2006/0051/2006A1124B.html

141 Règlement grand-ducal du 9 mai 2014 abrogeant: 1) le règlement grand-ducal modifié du 9 mai 2003 portant application de la directive 2001/80/CE du Parlement européen et du Conseil du 23 octobre 2001 relative à la limitation des émissions de certains polluants dans l'atmosphère en provenance des grandes installations de combustion; 2) le règlement grand-ducal modifié du 4 juin 2001 portant - application de la directive 1999/13/CE du Conseil du 11 mars 1999 relative à la réduction des émissions de composés organiques volatils dues à l'utilisation de solvants organiques dans certaines activités et installations - modification du règlement grand-ducal modifié du 16 juillet 1999 portant nomenclature et classification des établissements classés; 3) le règlement grand-ducal du 19 décembre 1989 relatif aux déchets provenant de l'industrie du dioxyde de titane; 4) le règlement grand-ducal modifié du 19 décembre 2002 concernant l'incinération des déchets. http://legilux.public.lu/eli/etat/leg/rgd/2014/05/09/n1/jo

142 Loi du 18 décembre 2015 modifiant la loi du 21 mars 2012 relative aux déchets

open burning of waste, which is considered as an uncontrolled management of waste. This includes the ban on cremation of green waste, household and non-domestic waste in the open air. Waste fines imposed for non-compliance with this provision are fixed in the Grand-Ducal Regulation of 18 December 2015 [143]. Indeed, a fine of 145 € is imposed for open burning of waste and even 250 € for open burning of non-domestic waste. Many municipalities have also implemented this prohibition in their respective municipal regulations.

7.2 Solid Waste Disposal (5A)

7.2.1 Source Category Description

The following section describes GHG emissions resulting from solid waste disposal on land (SWDL), which only originate from managed waste disposal sites in Luxembourg. As there are no unmanaged or other waste disposal sites any more (Table 7–3, Box "*Unmanaged Landfill Sites*"), emissions from IPCC category *5A – Solid Waste Disposal* are equal to the one deriving from IPCC subcategory *5A1 – Managed Waste Disposal Sites*.

Municipal waste is either directly or indirectly landfilled after treatment. Indirectly landfilled waste undergoes mechanical and biological pre-treatment prior landfilling. However, the emissions deriving from the treatment processes of waste are addressed under CRF subcategory *5B1* (Figure 7–3).

In 2015, the source category *5A* was responsible for 57.19% of emissions related to waste treatment under Section *5*, and for 8.55% of the total **methane** emissions estimated for Luxembourg (15.08% in 1990). It represented 0.54% of the total **GHG** emissions (excluding LULUCF) (0.81% in 1990). Neither CO_2 (biogenic origin), nor N_2O emissions (not significant) derived from non-biological or inorganic waste sources have been identified so far.

The source category *5A – Solid Waste Disposal* has been identified as a **key category** for CH_4 for the periods 1995-2004 and 2007-2009 (level assessment excluding LULUCF).

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143 Règlement grand-ducal du 18 décembre 2015 relatif aux avertissements taxés déterminant les modalités d'application de l'avertissement taxé et établissant un catalogue des contraventions soumises à l'avertissement taxé prévu par la loi modifiée du 21 mars 2012 relative aux déchets. http://www.legilux.public.lu/leg/a/archives/2015/0256/a256.pdf

7.2.2 Methodological Issues

7.2.2.1 Data Origin

The syndicates responsible for the MSW management submit an annual report, in which all the waste delivered to their landfill or incineration site is reported, to the Environment Agency. Due to the agreements between the syndicates, adjustments to the quantities of the annual reports had to be made in order to avoid double counting:

- Since 2004, the syndicate SIDEC put into operation a mechanical-biological treatment plant from which a calorific fraction is separated and delivered to SIDOR for combustion. To avoid double counting, the calorific fraction is deducted from SIDOR's MSW.

- SIGRE's syndicate has biodegradable waste (CED2 200201) in its balance sheet, which is composted and only considered in the subsector *5B1* of the National Inventory Report. To avoid double counting, biodegradable waste is deducted from SIGRE's MSW.

The IPCC category *5A* covers all waste disposal on land, or landfilled waste, which is organized *via* regional disposal districts (as listed in Table 7–3) as well as industrial waste deposited at Ronnebierg (Box "*Industrial Waste Disposal Site Ronnebierg*"). Today, Muertendall (managed by SIGRE in the Eastern district) is the only controlled landfill site active.

Industrial Waste Disposal Site Ronnebierg

The deposit of industrial waste in Ronnebierg ended in the 1960s or the beginning of the 1970s. The exact date is unknown. Then, Luxembourg's single industrial waste disposal on land site has been closed at the end of 1994, and was sanified between 1997 and 2000. These works included the sealing of the landfill, and the construction of a drainage water system.

According to a study from 1995, it can be assumed that a total of about 959,000 m^3 of waste had been deposited until the closure of the landfill. The study further revealed that waste deposited could be divided into the following essential fractions: household waste (20%), SIDOR slag (50%), demolition waste between 1974 and 1990 (6%), shredding, plastic, carton and glass waste (15%), various sludge (7%) and other (2%).

In the framework of the rehabilitation of the landfill, regular controls of the landfill condition as well as measurements of emissions have been performed at the Ronnebierg site since 2000 (except for 2001). These measurements are annually reported to the Environment Agency, and hence used for estimating emissions from this closed site for the period 1990 to 2015. For the years before 2000, no data on total quantity collected or deposited during its operating period nor composition is available, and hence an estimation of emissions has been extrapolated. The emissions from the closed landfill site for industrial waste, Ronnebierg, have been included in the category *5A* (see Table 7-9).

Table 7-4 – Total Municipal Solid Waste in Luxembourg (1990-2015)

Total MSW

Year	Total MSW Gg	*Incineration Gg*	Managed Waste for Disposal Gg	Population #	MSW / capita *kg / hab.*
1990	223.60	135.97	87.63	*379 300*	*589.51*
1991	216.80	142.26	74.54	*384 400*	*564.00*
1992	195.52	141.85	53.67	*389 600*	*501.86*
1993	200.98	134.95	66.03	*394 800*	*509.06*
1994	196.10	132.03	64.07	*400 200*	*490.01*
1995	194.76	126.09	68.67	*405 700*	*480.06*
1996	191.62	97.55	94.06	*411 600*	*465.54*
1997	192.58	115.56	77.02	*416 900*	*461.94*
1998	189.02	113.28	75.74	*422 100*	*447.80*
1999	196.81	129.69	67.12	*427 400*	*460.48*
2000	187.72	125.99	61.73	*433 600*	*432.93*
2001	190.03	124.40	65.63	*439 000*	*432.87*
2002	192.34	126.32	66.02	*444 000*	*433.19*
2003	191.18	122.86	68.32	*448 300*	*426.45*
2004	193.65	125.79	67.86	*455 000*	*425.61*
2005	196.06	121.14	74.92	*461 200*	*425.10*
2006	189.83	124.03	65.80	*469 100*	*404.68*
2007	193.48	127.69	65.80	*476 200*	*406.31*
2008	193.82	127.54	66.27	*483 800*	*400.61*
2009	194.04	126.72	67.32	*493 500*	*393.19*
2010	191.15	117.06	74.08	*502 100*	*380.70*
2011	192.09	125.36	66.73	*511 800*	*375.32*
2012	190.83	123.03	67.80	*524 900*	*363.56*
2013	185.48	119.04	66.44	*537 000*	*345.41*
2014	188.62	119.11	69.51	*549 700*	*343.13*
2015	212.48	138.54	73.94	*563 000*	*377.41*
Trend 1990-2015	*-4.97%*	*1.89%*	*-15.63%*	*48.43%*	*-35.98%*
Trend 2014-2015	*12.65%*	*16.31%*	*6.37%*	*2.42%*	*9.99%*

Sources: STATEC, *Statistical Yearbook*, Table A.3301, adjusted to the quantities of the annual reports according to Chapter 7.2.2.1

http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=13939&IF_Language=fra&MainTheme=1&FldrName=3&RFPath=65

Table 7-4 illustrates that the majority of Total MSW is incinerated in the municipal waste incinerator SIDOR (138.54 Gg in 2015) in comparison to solid waste management (73.94 Gg in 2015).

Table 7-5 lists the amount of MSW managed by the solid waste disposal sites (excluding the part of the waste destined to incineration, addressed under *1A1a*).

The quantities of **recovered CH_4** from landfilled waste (Table 7-12) were measured by the landfill operators and determined from their monthly reports.

Table 7-5 – Managed Waste at SWDS sites (1990 - 2015)

Managed Waste at SWDS sites *Trend by landfill site*					
Year	**Managed Waste for Disposal *Gg***	**SIDEC *Gg***	**SIGRE *Gg***	**SIDA *Gg***	**Ronnebierg *Gg***
1990	87.63	*58.23*	*18.40*	*11.00*	*NA*
1991	74.54	*39.34*	*24.60*	*10.60*	*NA*
1992	53.67	*38.11*	*5.46*	*10.10*	*NA*
1993	66.03	*39.26*	*13.71*	*13.06*	*NA*
1994	64.07	*45.53*	*18.55*	*NO*	*NA*
1995	68.67	*47.31*	*21.36*	*NO*	*NO*
1996	94.06	*51.02*	*43.04*	*NO*	*NO*
1997	77.02	*42.02*	*35.00*	*NO*	*NO*
1998	75.74	*41.90*	*33.84*	*NO*	*NO*
1999	67.12	*40.55*	*26.57*	*NO*	*NO*
2000	61.73	*41.60*	*20.13*	*NO*	*NO*
2001	65.63	*43.02*	*22.60*	*NO*	*NO*
2002	66.02	*42.02*	*24.00*	*NO*	*NO*
2003	68.32	*42.45*	*25.87*	*NO*	*NO*
2004	67.86	*43.94*	*23.92*	*NO*	*NO*
2005	74.92	*42.68*	*32.23*	*NO*	*NO*
2006	65.80	*38.31*	*27.49*	*NO*	*NO*
2007	65.80	*39.40*	*26.40*	*NO*	*NO*
2008	66.27	*39.57*	*26.71*	*NO*	*NO*
2009	67.32	*39.21*	*28.11*	*NO*	*NO*
2010	74.08	*39.32*	*34.76*	*NO*	*NO*
2011	66.73	*39.39*	*27.34*	*NO*	*NO*
2012	67.80	*39.70*	*28.10*	*NO*	*NO*
2013	66.44	*39.19*	*27.25*	*NO*	*NO*
2014	69.51	*39.39*	*30.13*	*NO*	*NO*
2015	73.94	*37.47*	*36.47*	*NO*	*NO*
Trend 1990-2015	*-15.63%*	*-35.66%*	*98.23%*	*NA*	*NA*
Trend 2014-2015	*6.37%*	*-4.88%*	*21.07%*	*NA*	*NA*

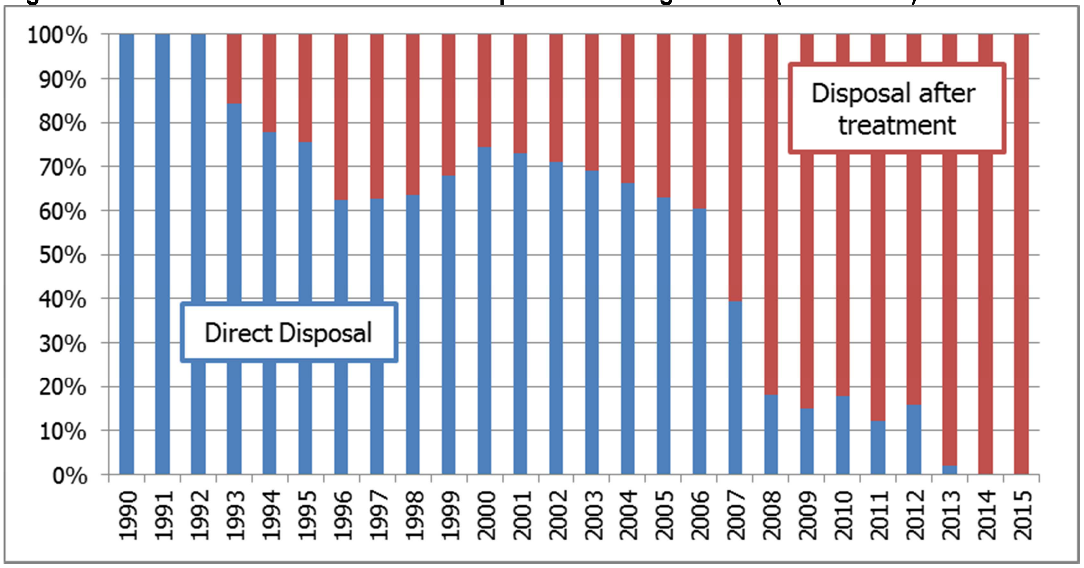
Sources: STATEC, *Statistical Yearbook*, Table A.3301, adjusted to the quantities of the annual reports according to Chapter 7.2.2.1
http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=13939&IF_Language=fra&MainTheme=1&FldrName=3&RFPath=65
STATEC, *Statistical Yearbook*, Table B.1100:
http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=12856&IF_Language=fra&MainTheme=2&FldrName=1

7.2.2.2 Methodology

Figure 7-4 illustrates the evolution of the shares of the direct and indirectly deposited MSW for Luxembourg, which in total accounts for up to 15.32 Gg in 2015.

- The first sudden drop in share of direct disposal in 1993/1994 can be explained by the closure of SIDA and the beginning of mechanical-biological pre-treatment at SIGRE.
- The second sudden drop in share of direct disposal in 2006/2007 is due to the biological pre-treatment of solid waste prior landfilling at SIDEC.

Figure 7-4 – Shares of Direct or Indirect Disposal of Managed MSW (1990 - 2015)



It has to be noted that from 2014 on no waste has been deposited any more without being pre-treated (due to the Landfill Ordinance, see Section 7.1.4.), so since 2014 no direct disposal of municipal solid waste has been reported by landfill operators.

For the SIDEC landfill Fridhaff, differentiation had been done between directly deposited waste on land (only occurs till 2014), and indirectly [144] deposited waste on land. For the SIGRE landfill Muertendall no further differentiation occurs for the waste, since there all waste is subjected before the landfill installation of a uniform treatment (aerobic treatment).

7.2.2.2.1 Directly Deposited Waste (SIDEC)

Amounts of generated solid waste have originally been estimated by volume only, but since the 1990's waste is categorized according to the (cumulated energy demand, CED[145] 2nd version) European Waste Catalogue. The fractions of waste listed in Table 7-6 are included.

The composition of the waste is analysed in a 5-year cycle. Composition analysis of both, residual (CED 200301 and 200399) and bulky waste (CED 200307), directly deposited is being used to subsequently determine the weight of the IPCC waste fractions to which **default degradable organic carbon (DOC) contents** are applied (Table 7-6). It is worth noting that the waste not included in the direct disposal is the demolition waste which is not deposited.

144 After having undergone mechanical sorting at SIDEC (separation of high calorific fraction and metals), and undergoing biological or aerobic treatment at SIDEC and SIGRE.

145 http://www.environnement.public.lu/dechets/informations_pratiques/CED/code_europeen_en.pdf

Demolition waste which is of purely inorganic nature is either recycled (up to 92.6% in 2013) or deposited at special demolition waste sites (521 Gg in 2013) together with excavated earth (7126 Gg in 2013).

Table 7-6 – Waste Fractions and Estimated Degradable Organic Carbon

CED	*Description*	*Estimated DOC*
200301	Mixed municipal waste	Residual waste composition
200399	Municipal waste, not otherwise specified	
200307	Bulky waste	Bulky waste composition
190801 (1)	Wastes from wastewater treatment plants – screenings	90 %
190802 (2)	Wastes from wastewater treatment plants – waste from de-sanding	50 %
200303 (3)	Street-cleaning residues	20 %
200201	Garden and park waste, biodegradable waste	100 %

Note: (1) Sächsisches Landesamt für Umwelt und Geologie 2006: Klärschlammkonzeption

(2) Hitzler Andreas: Beurteilung und Optimierung von Sandwaschanlagen im Einsatz auf Kläranlagen; Dissertation Universität Fridericiana zu Karlsruhe (TH), 2002

(3) Bayerisches Landesamt für Umwelt Infoblatt Abfallwirtschaft, Straßenkehrricht Mai 2010

The respective **emissions** can be estimated by the use of a *multiphase model (three phase model)*, an approach with which several organic element groups can be distinguished in the waste through their half-lives.

The spreadsheet based on the **First Order Decay (FOD) method** implementing the **Tier 1** methodology from the IPCC 2006 Guidelines for national GHG inventories has been used to estimate CH_4 emissions from SWDS. The method takes into account the decomposable degradable organic carbon ($DDOC_m$) accumulated (Equation 3.4) and the $DDOC_m$ decomposed (Equation 3.5) under anaerobic conditions in the SWDS at the end of a given year. According to K.-U. Heyer *et al.*, the anaerobic degradation proceeds relatively intensively with a higher gas production rate [146] during the first years of disposal.

7.2.2.2.2 Deposited Waste after Biological Pre-Treatment (SIGRE and SIDEC)

The pre-treatment of municipal waste before disposal leads to a substantial aerobic decay of the organic component. As a consequence, the behaviour of the decay in terms of reduction of the total mass and DOC_m is changing substantially.

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146 Methane emissions from MBT landfills. *Waste Management 2013 Sep;33(9):1853-60, K.-U. Heyer (2013)*

Since the pre-treatment of waste at the SWDS site Muertendall (managed by SIGRE) is performed uniformly without weighting prior to anaerobic digestion upon disposal, the reduction of the total mass has not been determined. In contrast to directly deposited waste, the biologically pre-treated solid waste is considered as ***bulk waste*** only as the amount and composition of the pre-treated waste being actually deposited after the rotting process cannot be exactly determined. In the current model, the resulting mass loss during the six-month rotting process is estimated to correspond to 50% of the mass of degradable organic compounds (DOC) in the deliveries (Table 7-8).

As proof of the degradation process and as set forth by the Landfill Directive, the landfill operators determined the respiration activity of waste after mechanical and biological treatment as a parameter of biologic reactivity and the rotting state of waste under aerobic conditions. The **AT_4 parameter** indicates the amount of O_2 consumed during the decomposition of the organic fraction of waste. SIDEC reported that AT_4 was reduced from 100 mg O_2/g TS (untreated waste) to 20 mg O_2/g TS (pre-treated waste) and provides proof of success of the biological pre-treatment of solid waste prior landfilling.

As the original composition of biologically treated waste cannot be derived, the generated emissions deriving from the biologically treated waste are back calculated according to the IPCC ***single-phase model*** based on the expertise of KÜHLE-WEIDEMEIER and BOGON [147].

7.2.2.3 Activity Data

To estimate the emissions from municipal solid waste generated by the municipalities, activity data was calculated based on the population and waste published in annual reports by the different landfill operators. Waste *per* capita was calculated based on statistics on the population from STATEC (Table 7-4).

As there were no national data on municipal waste production available for the years 1950 to 1989, data on waste *per* capita from Germany [148] were used from **1950 and 1975**. Municipal waste was completely landfilled till 1975. Luxembourg oriented its values near the IPCC default values but it has been assumed that, for 1950-1974, the fractions "*food*", "*paper*" and "*wood*"

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147 Kühle-Weidemeier M. und Bogon H., Methanemissionen aus passiv entgasten Deponien und der Ablagerung von mechanisch-biologisch behandelten Abfällen - Emissionsprognose und Wirksamkeit der biologischen Methanoxidation; Fachgutachten im Auftrag des Umweltbundesamtes, Dezember 2008

148 TU Berlin, Abfallbelastung und Entsorgungsplanung (Prof. Dr. Dr. B.-M. Wilke: Bachelorstudiengang Landschaftsplanung 06341500 L 05); Sekundärdatenquelle aus 2009.

landfilled were lower. The difference was allocated to a higher extent to the fraction "*plastics, other inert*".

In 1976, the incinerator of SIDOR opened and waste incinerated was attributed in accordance of the population living in the SIDOR municipalities. The relevant emission carriers for this estimation are the following: "*food*", "*garden*", "*paper*", "*wood*", "*textiles*" and "*nappies*". Adaptations for the fraction "*food*" were made for **1975-1991** in accordance to the IPCC default values. One-way nappies appeared in the 1970s and were allocated to the waste composition.

Activity data for Luxembourg for the year **1990** were calculated to 590 kg MSW produced *per* capita (Table 7-4), which was similar to the IPCC default values (*i.e.* 490 kg MSW produced *per* capita, IPCC Table 2A.1). Waste composition is exactly known since 1992 and has been calculated by the use of periodical sample analyses at the landfill operators. The data from the national waste composition analysis 1992/94 were used till 2003. The Waste Division at the Environment Agency delivers activity data from 1990 **up to the year 2015**, taking into account the effect of aerobic decomposition at SIGRE (since 1993) and SIDEC (since 2007). For 2010-2015 values of the composition of the bulk and residual waste are as of 2009/2010 and 2014.

7.2.2.3.1 Directly Deposited Waste (SIDEC)

An overview of the composition trends of waste destined to direct disposal is given in Table 7-7.

In the time-series, significant changes in the composition of directly landfilled waste are noticeable. In particular due to a differentiated consideration of the waste composition, a significantly higher proportion of wood (from 1% in 2003 to 28% in 2004) and a sharp decline of the wood fraction (starting in 2006) are attributable to the fact that:

- Before 2004, the composition of deposited waste was considered to correspond to the residual waste composition only.
- From 2004 onwards, the composition of the deposited waste was estimated according to the waste type and the pretreatment method (*bulk waste model*). Large quantities of bulky waste were declared by SIDEC in 2004 and 2005, and due to the separate consideration of bulk waste (containing wood at around 60% w/w in 2004) for directly deposited waste, the proportion of wood was significantly increased.

Table 7-7 – Composition Trends of Waste destined to Direct Disposal: 1950-2015

Year	Food	Garden	Paper	Wood	Textile	Nappies	Plastics, other inert	Total
1950-1974	20%	0%	25%	5%	0%	0%	50%	100%

1975-1980	24%	1%	25%	11%	1%	1%	37%	100%
1981-1984	24%	1%	24%	11%	1%	2%	37%	100%
1985-1991	29%	4%	20%	11%	1%	2%	33%	100%
1992 - 2003	39%	8%	16%	1%	1%	5%	30%	100%
2004	19%	6%	12%	28%	6%	3%	25%	100%
2005	17%	5%	13%	26%	6%	3%	29%	100%
2006	28%	5%	16%	13%	4%	4%	30%	100%
2007	24%	6%	16%	12%	5%	4%	33%	100%
2008	17%	7%	17%	13%	8%	4%	35%	100%
2009	28%	3%	14%	13%	4%	5%	33%	100%
2010	33%	6%	11%	12%	2%	3%	33%	100%
2011	42%	5%	10%	10%	1%	3%	29%	100%
2012	44%	5%	12%	6%	1%	4%	29%	100%
2013	46%	5%	9%	5%	1%	5%	30%	100%
2014 - 2015	0%	0%	0%	0%	0%	0%	0%	0%

Note: Percentages of waste fractions refer to the Managed MSW to SWDS.

7.2.2.3.2 Deposited Waste after Biological Treatment (SIGRE and SIDEC)

The different phases and duration of MBT have an effect on the generation of emissions from waste. During **mechanical sorting**, the high calorific fraction[149] and metals are separated from the waste.

- The separated **high calorific fraction** of approximately 9.34 Gg (for the year 2015) is destined to waste incineration at SIDOR. This relationship is clearly made visible when looking at the time-series of waste amounts being incinerated and being landfilled (Figure 7-5). In 1996, for example, the sharp increase of solid waste disposed at SIGRE and to a smaller extent at SIDEC can be explained by a sharp decrease of waste incinerated at SIDOR (shut-down for 3 months due to a fire [150]).

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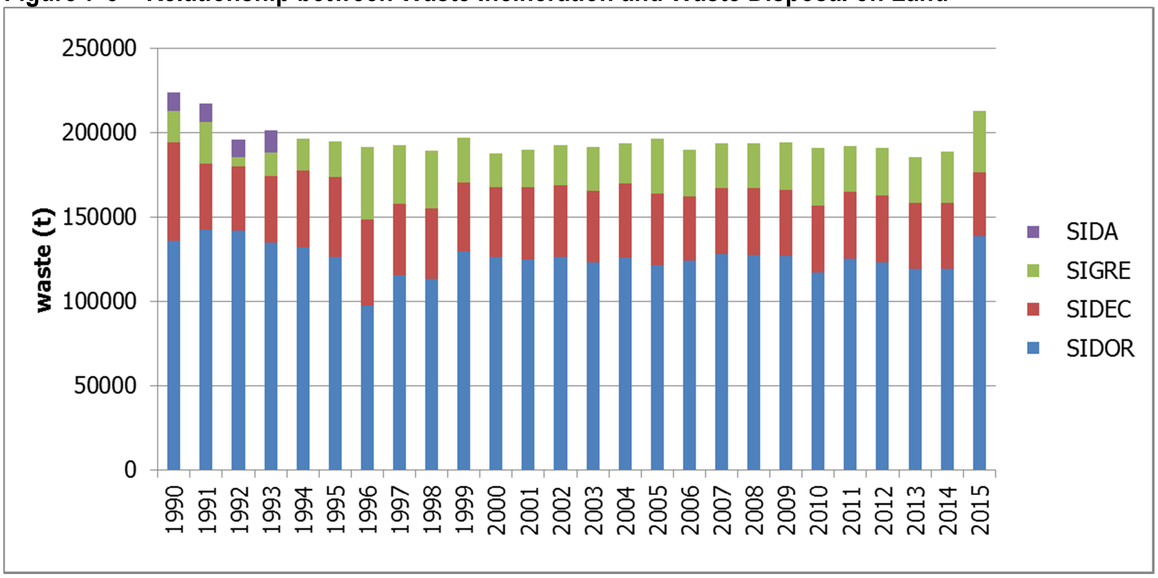
149 The deriving high calorific (combustible) fraction (> 150mm) is incinerated (addressed under CRF subcategory *1A1a*) at the municipal waste incinerator SIDOR. Energy generation from 9000 tons of high calorific fraction accounts for electronic power supply for 1600 households.

150 De Journal, N.200, p.7, "SIDOR: Feiern in der Zeit des Umbruchs"

- In 2005, the % of total MSW being categorized as "*plastics, other inert*" [151] added up to 33% destined to aerobic pre-treatment. The percentage of this fraction increased to around 45% as the amount of total MSW waste being directly landfilled was diminished to zero in 2014 (Figure 7-4).

Figure 7-5 – Relationship between Waste Incineration and Waste Disposal on Land



Sources: STATEC, *Statistical Yearbook*, Table A.3301, adjusted to the quantities of the annual reports according to Section 7.2.2.1
http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=13939&IF_Language=fra&MainTheme=1&FldrName=3&RFPath=65

Biological pre-treatment of municipal waste before the disposal leads to a substantial aerobic decay of the organic component and as a consequence, the behaviour of the decay (in terms of reduction of the total mass and DOC_m) is changing substantially. The practical reductions depend on the type and duration of MBT in question. In this sense, it is worth noting that waste without mechanically sorted fractions has then been treated differently at SIGRE and SIDEC.

- At **SIDEC**, waste fractions are cycling every two weeks in heaps from which up to 18 000 tons of remaining lixiviate are collected in a basin. Pre-treatment of waste induces a reduction of the organic pollution of lixiviate in total organic carbon (TOC) from 3000 mg/L (untreated waste) to < 250 mg/L (pre-treated waste). In 2015, the TOC content in the pre-treated waste residues accounts for around 20%. As the TOC also contains non-degradable organic carbon, the value for the dissolved organic carbon value has been estimated with

151 "*Plastics, other inert*" corresponds to inert waste, *i.e.* not containing degradable organic carbon (DOC=0), *e.g.* glass, metals *etc.*

the aid of the weighted average of the DOC calculated from the waste composition of the input material (Table 7-8, column % DOC content).

- The aerobic treatment at the **SIGRE** landfill Muertendall is performed using forced aerated windrows of 36 tons in which large streams of waste undergo a systematic six-month-rotting process. The resulting waste is then installed directly without weighing in the landfill. SIGRE states that the TOC content of the input waste is reduced from 25.5% to 14.1% during treatment.

Table 7-8 – Mass and DOC reduction of pre-treated MSW: 1990-2015

Managed Solid Waste Disposal										
Year	Managed MSW			Input Biological Treatment			Biological Treatment		Indirect Disposal Output *Gg*	Total Disposal *Gg*
	Total *Gg*	Direct	Indirect	Initial Mass *Gg*	DOC content %	DOC content *Gg*	Mass Reduction %	DOC Reduction *Gg*		
1990	87.63	87.21								87.21
1991	74.54	73.71								73.71
1992	53.67	52.79								52.79
1993	66.03	52.49	13.53	13.53	*22.5%*	3.04	28.0%	1.52	9.74	62.24
1994	64.07	45.81	18.26	18.26	*22.5%*	4.10	28.0%	2.05	13.16	58.97
1995	68.67	47.09	21.58	21.58	*22.5%*	4.85	29.4%	2.42	15.24	62.33
1996	94.06	50.95	43.11	43.11	*22.5%*	9.68	28.9%	4.84	30.66	81.61
1997	77.02	42.02	35.00	35.00	*22.5%*	7.86	28.8%	3.93	24.91	66.93
1998	75.74	41.86	33.88	33.88	*22.5%*	7.61	28.9%	3.80	24.10	65.96
1999	67.12	40.46	26.65	26.65	*22.5%*	5.99	29.0%	2.99	18.93	59.39
2000	61.73	41.71	20.02	20.02	*22.5%*	4.50	28.5%	2.25	14.30	56.01
2001	65.63	42.93	22.70	22.70	*22.5%*	5.10	30.3%	2.55	15.82	58.75
2002	66.02	42.74	23.28	23.28	*22.5%*	5.23	25.9%	2.61	17.26	60.00
2003	68.32	41.29	27.02	27.02	*22.5%*	6.07	31.7%	3.03	18.45	59.75
2004	67.86	32.51	35.35	35.35	*32.6%*	11.53	53.3%	5.76	16.51	49.02
2005	74.92	39.23	35.69	35.69	*32.1%*	11.44	35.1%	5.72	23.15	62.38
2006	65.80	31.36	34.44	34.44	*28.4%*	9.78	40.4%	4.89	20.52	51.88
2007	65.80	17.10	48.69	48.69	*27.9%*	13.61	46.1%	6.80	26.23	43.33
2008	66.27	7.42	58.85	58.85	*29.7%*	17.49	43.2%	8.75	33.44	40.86
2009	67.32	5.89	61.43	61.43	*27.2%*	16.74	45.4%	8.37	33.54	39.44
2010	74.08	7.86	66.22	66.22	*27.2%*	17.98	45.5%	8.99	36.06	43.93
2011	66.73	4.34	62.39	62.39	*26.1%*	16.27	49.9%	8.13	31.28	35.62
2012	67.80	5.88	61.92	61.92	*24.4%*	15.12	49.4%	7.56	31.33	37.21
2013	66.44	0.70	65.74	65.74	*24.5%*	16.10	50.2%	8.05	32.76	33.46
2014	69.51	0.00	69.51	69.51	*24.5%*	17.02	51.0%	8.51	34.03	34.03
2015	73.94	0.00	73.94	73.94	*24.5%*	18.11	79.3%	9.05	15.32	15.32
Trend 1990-2015	*-15.63%*									*-82.43%*
Trend 2014-2015	*6.37%*									*-54.98%*

Note: The resulting mass loss is estimated to amount up to 50% of the mass of DOC in the deliveries (Table 7-8).

The amount of MB-treated MSW finally deposited in the landfills is listed as a residue of biological treatment in Table 7-8. In 2015, 100% of the managed MSW results in around 15.32 Gg of waste, which is deposited. The sudden drop between 2014 and 2015 can be explained by the fact that solid waste from SIDEC is undergoing a second pre-treatment at SIGRE before being landfilled in the single landfill in Luxembourg, Muertendall.

Table 7-9 – CH_4 emissions from *5A1 - Managed Waste Disposal Sites*: 1990-2015

CH_4 emissions from 5A1 - Managed Waste Disposal Sites

Year	Total	SIDEC, SIGRE, SIDA		Ronnebierg	IEF
	Gg	direct	indirect	*Gg*	*kg / t MSW*
1990	3.83	3.53	*NO*	*0.30*	*43.71*
1991	3.90	3.63	*NO*	*0.27*	*52.34*
1992	3.90	3.65	*NO*	*0.25*	*72.71*
1993	3.84	3.60	*0.00*	*0.23*	*58.10*
1994	3.48	3.22	*0.04*	*0.21*	*54.28*
1995	3.46	3.17	*0.10*	*0.19*	*50.36*
1996	3.46	3.13	*0.16*	*0.17*	*36.76*
1997	3.54	3.11	*0.28*	*0.16*	*46.00*
1998	3.55	3.04	*0.37*	*0.14*	*46.88*
1999	3.55	2.98	*0.44*	*0.13*	*52.93*
2000	3.39	2.78	*0.49*	*0.12*	*54.92*
2001	3.35	2.73	*0.52*	*0.10*	*51.03*
2002	3.34	2.70	*0.55*	*0.09*	*50.61*
2003	3.35	2.69	*0.58*	*0.08*	*49.10*
2004	3.16	2.47	*0.62*	*0.07*	*46.54*
2005	3.05	2.35	*0.64*	*0.06*	*40.72*
2006	2.99	2.25	*0.69*	*0.04*	*45.37*
2007	2.95	2.19	*0.73*	*0.03*	*44.89*
2008	2.89	2.07	*0.79*	*0.03*	*43.57*
2009	2.84	1.94	*0.88*	*0.03*	*42.26*
2010	2.38	1.39	*0.95*	*0.03*	*32.11*
2011	2.37	1.31	*1.04*	*0.02*	*35.46*
2012	2.24	1.13	*1.10*	*0.01*	*33.05*
2013	2.28	1.12	*1.15*	*0.01*	*34.25*
2014	2.24	1.03	*1.20*	*0.01*	*32.24*
2015	2.13	0.86	*1.26*	*0.01*	*28.76*
Trend 1990-2015	*-0.44*	*-0.76*	*NA*	*-0.97*	*-0.34*
Trend 2014-2015	*-0.05*	*-0.17*	*0.05*	*0.04*	*-0.11*

Source: Environment Agency

Note: The amount of MSW deposited is the amount of MSW containing degradable organic carbon and thus excludes inert waste such as plastics, glass, *etc.*

Based on the assumption that exclusively *(i)* biologically relatively easily degradable fractions ("*Food*" and "*Nappies*"), and the *(ii)* partially readily biodegradable fractions "*Garden*" and "*Paper*" are included in the waste being treated biologically, the induced rotting loss in the biologically treated waste fractions due to loss of organic fraction and moisture in waste during biological pre-treatment has been estimated depending on the degradable organic carbon (DOC) content. The emissions are estimated according to the share of waste sent to landfills. Due to the lack of data on the actual amount and composition of landfilled waste, in particular for SIGRE, the resulting **mass loss** is estimated to amount up to 50% of the mass of DOC in the deliveries (Table 7-8).

The emissions deriving from the pre-treatment of solid waste prior to landfilling starting from 1993 are addressed under CRF subcategory *5B1*. Due to the reduced amount in material, organic content and biological activity, CH_4 emissions have been reduced by the treatment of at least 50% compared to normal disposal in SWDS without treatment. Table 7-9 illustrates *(i)* the methane emissions from solid waste disposal, as well as *(ii)* the implied emission factor.

7.2.2.4 Parameters

Table 7-10 gives an overview of the parameters used for the estimation of emissions from solid waste disposal on land.

Table 7-10 – Parameters used for the Calculation of Emissions

	Directly Deposited Waste	***Deposited Waste after Biological Treatment***
DOC (Degradable Organic Carbon) ***(weight fraction, wet basis)***	"*waste by composition*"	"*bulk waste data only*"
Food	0.15	
Garden	0.2	
Paper	0.4	
Wood	0.43	
Textile	0.24	
Nappies	0.24	
Bulk MSW		0.19
DOC_f (fraction of DOC dissimilated)	0.5	
Methane Generation Rate Constant (k) **(years^{-1})**		
Food	0.185	
Garden	0.1	
Paper	0.06	
Wood	0.03	
Textile	0.06	
Nappies	0.1	
Bulk MSW		0.08
Delay Time (months)	6	
Fraction of Methane (F) in generated landfill gas	0.5 (for 1950-2009) 0.4037 (for 2010-2015)	0.5
Conversion Factor, C to CH_4	1.33	

The kinetics of waste degradation under anaerobic conditions are dependent on the different climate zones. The climate zone for ***Western Europe, Luxembourg*** has been selected. While the option "*waste by composition*" has been selected for waste destined for **direct disposal**, the option of "*bulk waste data only*" has been chosen for waste after biological treatment.

Under the assumption that the SWDS environment is anaerobic and the DOC values include lignin[152], the default value for DOC_f in mechanical-biological pretreated waste applied is 0.5 (IPCC 2006, Chapter 2, Table 2.4).

For the years 1990-2009, the default setting of the IPCC was used for the fraction of methane in generated landfill gas (F= 0.5). It was adjusted from 2010 on, as from that point onwards the data on the proportion of methane in the captured landfill gas of the SIDEC were available. The adjusted value from 2010 corresponds to the average methane content of the years 2010 - 2014.

7.2.2.4.1 Methane Correction Factor (MCF)

From **1950** till the opening of SIDEC in 1972, municipal waste was deposited to unmanaged local landfills. Due to a lack of information, it was assumed that 50% were brought to unmanaged, shallow and 50% to unmanaged, deep landfills: the MCF of 0.4 and 0.8 have been applied to the activity data.

The controlled landfill of SIDEC was installed in **1972** and took over up to 20% of the total waste. When SIGRE was installed in **1979**, up to 80% of the total waste were managed by the two controlled landfill sites under anaerobic conditions. The MCF of 1 (IPCC 2006, Table 3.1) was applied to this share of activity data.

Since **1993**, all collected waste is accepted at the landfill sites which both, SIDEC and SIGRE, underwent several modernization procedures (*i.e.* leachate drainage system, regulating pondage, gas ventilation system at SIDEC) over time. Independently on whether waste is *(i)* landfilled directly or *(ii)* pre-treated at SIGRE (since 1993) or SIDEC (since 2007), the MCF of 1 is applicable to managed anaerobic landfills.

Since 2014, up to 100% of the waste has been treated biologically, and the induced aerobic decay prior to landfill of only low carbonic waste results in at least 50% less CH_4 emissions as compared to untreated waste.

No activity data was attributed to the type "*Uncategorized*" and "*Managed, semi-aerobic*". Table 7–11 gives an overview of the evolution of the MCF with regard to the waste management type.

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152 Oonk and Boom, *Landfill gas formation, recovery and emissions* (1995)

Table 7-11 – Methane Correction Factors and Waste Distribution by Waste Management Type

	Methane Correction Factor				
	Un-managed, shallow	*Un-managed, deep*	*Managed*	*Managed, semi-aerobic*	*Uncategorized*
Year	**0.4**	**0.8**	**1**	**0.5**	**0.6**
1950-1971	50%	50%	0%	0%	0%
SIDEC opened					
1972	45%	45%	10%	0%	0%
1973-1978	40%	40%	20%	0%	0%
SIGRE opened					
1979-1992	10%	10%	80%	0%	0%
SIDA closed, SIGRE aerobic treatment					
1993-2015	0%	0%	100%	0%	0%

Note: If parameters shown as "country-specific values" are identical to the IPCC default values, this means that the IPCC default value was used.

7.2.2.4.2 Methane Oxidation Factor

The methane oxidation factor (OX) indicates the fraction of emitted methane, which is oxidized in the surface layers of landfills. The default value of the methane oxidation factor, an OX of 0, has been used for the waste disposal from **1950** to 1993. **Since 1993**, landfill sites of SIGRE and SIDEC are considered as well-managed SWDS, and the OX has been fixed to 0.1 according to the expertise of KÜHLE-WEIDEMEIER and BOGON [153]. As the MBT residues are in many cases *not* placed in a separate landfill but in a section which is in connection with the existing landfill or on top of raw waste, the pre-treated waste is considered as CH_4 oxidising material (similar to compost or soil), following a recommendation by the TERT during the EU ESD review. The OX factor was applied after subtraction of CH_4 recovered.

7.2.2.5 CH_4 Recovery

The methane recovery systems have been installed at the individual landfills Muertendall (managed by SIGRE) and Fridhaff (managed by SIDEC) in the years 2000 and 2002,

153 Kühle-Weidemeier M. und Bogon H., Methanemissionen aus passiv entgasten Deponien und der Ablagerung von mechanisch-biologisch behandelten Abfällen - Emissionsprognose und Wirksamkeit der biologischen Methanoxidation -; Fachgutachten im Auftrag des Umweltbundesamtes, Dezember 2008

respectively. Since then[154], the individual landfills report the quantity of the captured landfill gas to the Environment Agency in accordance to their permits and to the statistical office for the purposes of the waste statistics. These detected quantities are included in the reported CH_4 recovery in the GHG inventory, which is taken from official waste statistics.

Table 7-12 – CH_4 Recovery from *5A1 – Managed Waste Disposal Sites*: 1990-2015

CH_4 Recovery from 5A1 - Managed Waste Disposal Sites

Year	Total *Gg*	SIDEC, SIGRE, SIDA *Gg*	Ronnebierg *Gg*
1990	NO	NO	*NO*
1991	NO	NO	*NO*
1992	NO	NO	*NO*
1993	NO	NO	*NO*
1994	NO	NO	*NO*
1995	NO	NO	*NO*
1996	NO	NO	*NO*
1997	NO	NO	*NO*
1998	NO	NO	*NO*
1999	NO	NO	*NO*
2000	0.15	0.15	*NO*
2001	0.15	0.15	*NO*
2002	0.14	0.14	*NO*
2003	0.10	0.10	*NO*
2004	0.30	0.30	*NO*
2005	0.31	0.31	*NO*
2006	0.34	0.34	*NO*
2007	0.32	0.32	*NO*
2008	0.31	0.31	*NO*
2009	0.27	0.27	*NO*
2010	0.28	0.28	*NO*
2011	0.26	0.26	*NO*
2012	0.34	0.34	*NO*
2013	0.27	0.27	*NO*
2014	0.26	0.26	*NO*
2015	0.35	0.35	*NO*
Trend 1990-2015	*NA*	*NA*	*NA*
Trend 2014-2015	*0.35*	*0.35*	*NA*

Source: Environment Agency

Note: The amount of MSW deposited is the amount of MSW containing degradable organic carbon and thus excludes inert waste such as plastics, glass, *etc.*

While the recovered CH_4 was used for the production of electricity at the SIGRE landfill Muertendall (> 50% methane), recovered gas was flared at the SIDEC landfill Fridhaff (35-40% methane). Methane emissions that are recovered by the systems installed at the SWDS sites, have already been subtracted from the estimated emissions in Table 7-9.

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154 For the year 2000, no data is available for the landfill Muertendall, so that the IPCC default for non-monitored data was used.

7.2.3 Uncertainties and Time-Series Consistency

Uncertainties from Activity Data

The information on activity data, composition and handling of solid waste on landfills in Luxembourg resembles the situation of Austria. The uncertainty assessment is originally based on an Austrian national study (Winiwarter, 2007), and was improved and revised by expert judgement for the submission 2017:

– In the legal framework of the EU Directive 2008/98/EC and the Landfill Directive 1999/31/EC, Luxembourg has elaborated also a similar Waste Strategy to Austria by setting up a waste national action plan[155].

– The advanced waste collection system, often with waste collection charges, allows the evaluation of annual quantities of municipal waste.

– The activity data of the collected amount of waste is considered to be complete.

– The type and composition of waste is also characterized by: lack of hazardous waste, introduction of aerobic pre-treatment prior landfilling, and high recycling rate (Box "*Recycling Rates for Packaging Waste*"). Regularly performed residual waste and bulky waste analysis as well as inspection activity on landfill according to ISO 17020 and ISO 17025 underlines the high quality of activity data available in Luxembourg.

An overall uncertainty from activity data has been assumed of ± 8%.

Uncertainties from EFs and Methodology Applied

Under the uncertainty of the model methodology are considered:

- Uncertainty of DOC: ± 20% (Table 3.5, IPCC 2006)
- Uncertainty for MCF : −10% to 0%
- Uncertainty for fraction of CH_4 in generated landfill gas: ± 5% (Table 3.5, IPCC 2006)
- Uncertainty for CH_4 recovery known for SIDEC and SIGRE: (Uncertainty of oxidation factor included) ± 10%
- Uncertainty for half-time $t_{1/2}$: ± 15% (Table 3.4, IPCC 2006)

155 *Plan national de gestion des déchets 2016*, http://www.environnement.public.lu/dechets/dossiers/pngd/index.html

- Uncertainty for delay period over 50 years: ± 30%

According to expert judgment, a combined uncertainty for the solid waste disposal sector (which includes the uncertainty deriving from the waste deposited, the MCF, the DOC content in the directly deposited and pre-treated waste, the CH_4 generation rate as well as the delay time) sums up to approximatively 42%.

7.2.4 Category-Specific QA/QC and Verification

Category-specific QA/QC and verification include:

- Internal verifications and plausibility checks when compiling aggregated activity data on waste from the waste disposal sites.
- QA/QC procedures described under the **Waste Statistics Regulation**[156] **(WStatR, Regulation EC No 2150/2002), regulation under the** Eurostat Directive on reporting waste data. Indeed, the same aggregated data used for the inventory is also used for reporting to Eurostat.

7.2.5 Category-Specific Recalculations Including Changes Made in Response to the Review Process

Following the recommendations of the In-Country **Review** of 2008 and the centralized review of 2009 (ARR 2009, § 106), the calculation of the emissions was made for time-series starting from 1950, and also taking into account the pre-treated waste being landfilled (emissions from pre-treatment of solid waste are addressed under CRF category *5B1*).

In 2016, the Environment Agency conducted two studies to assess:

1. the composition of the high calorific fraction from SIDEC, and
2. the emissions of the waste deposited at the landfills SIDEC and SIGRE.

In the latter study, "*emissions of the waste deposited at the municipal solid waste landfills*" have been revised for the period 1993-2009 (MCF of 1 applied to the time-series), and calculated for the years 2010-2015 (based on waste composition analysis of 2014). Table 7–13 and Table 7-14 present the main revisions and recalculations used to estimate CH_4 emissions from SWDS and relevant to CRF category *5A*.

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156 http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32002R2150&from=EN

Table 7-13 – Recalculations with Respect to Previous Submission 2016v1.1 in Category *5A*

Difference		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Managed Solid Waste	%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.78%	0.10%
CH_4 emissions	Gg	0.63	0.62	0.61	0.58	0.33	0.43	0.53	0.68	0.79	0.88	0.73	1.07	1.11
	%	19.83%	19.03%	18.39%	17.87%	10.57%	14.19%	18.08%	23.91%	28.49%	32.91%	27.49%	47.16%	50.05%
CH_4 recovery	Gg	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.15	0.00	0.00
	%	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00%	0.00%

Difference		2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Managed Solid Waste	%	1.47%	14.13%	2.37%	1.97%	25.89%	27.89%	39.94%	33.12%	47.89%	45.70%	46.42%	54.54%
CH_4 emissions	Gg	1.14	1.39	1.40	1.46	1.47	1.49	1.51	1.17	1.22	1.35	1.31	1.34
	%	51.54%	78.24%	84.28%	95.94%	98.97%	107.30%	112.61%	96.14%	107.01%	150.75%	136.87%	148.70%
CH_4 recovery	Gg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.18%	0.00%	0.00%	0.00%	0.00%

Table 7-14 – Changes in GHG Inventory since Submission 2016v1.1

GHG Source & Sink Category	Revisions 2016 v1 ➔ 2017v1.2	Type of Revision
5A – Waste *per* capita	The waste generation rate *per* capita is based on STATEC data adjusted to the quantities of the annual reports according to Chapter 7.2.2.1	Preliminary questions
5A – MCF	The validity of the methane correction factor has been assessed for the national circumstances and was changed from 0.1 to 1. The landfill receiving pre-treated waste residues is not classified anymore as an uncategorized landfill. Independently on whether waste is *(i)* landfilled directly or *(ii)* pre-treated at SIGRE (since 1993) or SIDEC (since 2007), the MCF of 1 is applicable to managed anaerobic landfills.	Updated MCF ARR 2014 ARR 2015, §75
5A – Transparency	Emissions from the deposition of pre-treated residues is now reported under *5A* for the year 1993 onwards, except for emissions from rotting process (reported under *5B1*)	Improved transparency ARR 2013, §69
5A – Recovery	Methane recovery from solid waste disposal on land was changed for the year 2000	Updated emissions ARR 2013, §70
5A – OX	The values of the methane oxidation factor OX have been adapted according to the waste disposal and the introduction of pre-treatment of solid waste	ARR 2012, §104 CF 2014
5A – Uncertainties	Revisited assessment of the sector-specific uncertainty and transfer from the general NIR chapter 1.7 to the sector-specific chapter	ARR 2012 CR 2014

7.2.6 Category-Specific Planned Improvements including those in Response to the Review Process

To obtain the exact DOC value of pre-treated waste residues and validate the estimations in Table 7-8, material is planned to be analysed in the framework of a research project.

7.3 Biological Treatment of Solid Waste (5B)

7.3.1 Source Category Description

Under the IPCC category *5B – Biological Treatment of Solid Waste*, GHG emissions originate from composting and biological pre-treatment of solid waste prior to landfill (*5B1 - Biogenic waste composted at centralised composting plants*), as well as from anaerobic treatment (*5B2 - Biogenic waste treated in biogas plants*).

In 2015, this source category was responsible for 31.41% of the total GHG emissions from the waste sector and it represented 0.30% of the total GHG emissions in CO_2e (excluding LULUCF). For each of the gases reported in 2015:

- CH_4 represented 26.8% of waste treatment methane related emissions (excluding *5C - Incineration and Open Burning of Waste*) and 3.34% of the total methane emissions estimated for Luxembourg;
- N_2O represented 54.4% of waste treatment nitrous oxide related emissions (excluding *5C - Incineration and Open Burning of Waste*) and 3.04% of the total nitrous oxide emissions estimated for Luxembourg.

Neither CO_2 (biogenic origin), nor N_2O emissions (negligible) derived from non-biological or inorganic waste sources have been identified so far. The CRF category *5B - Biological Treatment of Solid Waste* is not a key category.

7.3.1.1 Biogenic Waste Composted at Centralised Composting Plants (*5B1*)

Composting is an aerobic process and a large fraction of the degradable organic carbon (DOC) in the waste material is converted into CO_2, water and heat. CH_4 is only formed in oxygen-deprived sections of the compost, and can be oxidized during aerobic treatment. Composting also produces N_2O emissions, depending on the initial nitrogen content of the material. These are reported under subcategory *5B1a - Municipal Solid Waste.*

Biological pre-treatment of solid waste prior landfilling, during which air is forcedly blown through the bulk waste to speed up its decomposition, has been systematically performed since SIGRE has first introduced aerobic treatment processes for the managed waste in 1993. At SIDEC, a mechanical-biological treatment (MBT) plant has been installed treating mixed waste since 2007 (Table 7-3). Disposal of waste and its residues after treatment are reported under CRF category *5A*, while the CH_4 and N_2O emissions generated during the rotting process are considered under subcategory *5B1b Other – MBA treated MSW.*

7.3.1.1 Biogenic Waste Treated in Biogas Plants (*5B2*)

Anaerobic digestion of organic waste results in CH_4 generation which is used to produce heat and/or electricity, wherefore reporting of emissions from the process is usually done in the Energy Sector (see Sections 3.2.6, 3.2.9.2, and 3.2.9.4) according to IPCC Guidelines. Emissions of CH_4 from biogas plants due to unintentional leakages during process disturbances or other unexpected events are estimated to be between 0 and 10 % of the amount of CH_4 generated (Volume 5, Chapter 4, Paragraph 4.1, IPCC 2006). N_2O emissions from *5B2 – Biogenic Waste Treated in Biogas Plants* are assumed negligible.

Table 7-15 – CH_4 & N_2O Emission Trends for Category *5B – Biological Treatment of Solid Waste*: 1990-2015

5B - Biological Treatment of Solid Waste

Year	Emissions (Gg) CO_2	CH_4	N_2O	Total in CO_2e
1990	*NO*	*NO*	*NO*	NO
1991	*NO*	*NO*	*NO*	NO
1992	*NO*	*0.01*	*0.00*	0.25
1993	*NO*	*0.06*	*0.00*	2.49
1994	*NO*	*0.08*	*0.00*	3.12
1995	*NO*	*0.09*	*0.00*	3.74
1996	*NO*	*0.14*	*0.01*	5.79
1997	*NO*	*0.15*	*0.01*	6.42
1998	*NO*	*0.19*	*0.01*	8.08
1999	*NO*	*0.18*	*0.01*	7.47
2000	*NO*	*0.28*	*0.02*	11.66
2001	*NO*	*0.30*	*0.01*	11.82
2002	*NO*	*0.35*	*0.02*	13.99
2003	*NO*	*0.45*	*0.02*	17.92
2004	*NO*	*0.48*	*0.02*	18.51
2005	*NO*	*0.55*	*0.02*	20.90
2006	*NO*	*0.62*	*0.03*	23.07
2007	*NO*	*0.66*	*0.03*	24.43
2008	*NO*	*0.80*	*0.03*	29.67
2009	*NO*	*0.80*	*0.03*	28.86
2010	*NO*	*0.81*	*0.03*	29.12
2011	*NO*	*0.75*	*0.03*	26.57
2012	*NO*	*0.79*	*0.03*	27.86
2013	*NO*	*0.79*	*0.03*	27.96
2014	*NO*	*0.83*	*0.03*	29.26
2015	*NO*	*0.83*	*0.03*	29.21
Trend 1992-2015	*NA*	*8152.72%*	*NA*	*11521.15%*
Trend 2014-2015	*NA*	*0.24%*	*-1.10%*	*-0.15%*

Source: Environment Agency.

Table 7-15 shows that CH_4 and N_2O emissions, generated by *5B – Biological Treatment of Solid Waste* increased over time as a result of the increasing amount of waste composted and undergoing biological pre-treatment prior landfilling (since 1993). In addition, as Luxembourg has committed itself under the Kyoto Protocol to an increased share of electricity produced from renewable sources, fugitive CH_4 emissions from the use of biomass in anaerobic digesters have accumulated (since 1992).

7.3.2 Biogenic Waste Composted at Centralised Composting Plants (*5B1*)

7.3.2.1 Methodological Issues

7.3.2.1.1 Data Origin

Composting

In the CRF subcategory *5B1*, composting covers seven composting installations that exist in Luxembourg, plus one that co-composts sewage sludge[157]:

– Various local municipalities (*e.g.* Mondercange, Mamer, Hesperange, Ville de Luxembourg) operate their own composting installation, hence all households are covered by a collection scheme for biodegradable waste which is included in the activity data for *5B1 – Composting*. These composting installations operate in part under anaerobic conditions, with a residence time in the composter of a few weeks. Table 7-16 lists the amount of compostable waste collected from households and commercial activities and shows that the majority of green waste is collected in the composting installation MINETT-Kompost Mondercange.
– The plant which co-composts sewage sludge, Soil-Concept, uses active ventilation and operates fully aerobic, without methane formation.

Activity data for compost production are taken from:

- STATEC, *Statistical Yearbook*, Table A.3306 (prepared by the Waste Division of the Environment Agency based on annual reports from 1993-2015) for the composting installations;
- Annual reports transmitted to the Waste Division of the Environment Agency for the Soil-Concept installation (Box *"Soil Concept"*).

[157] Sewage sludge is allocated to the CRF Sector *3D - Agriculture*.

Soil-Concept [158]

Since 1996, Soil-Concept has been working on a project with the inter-municipal syndicate SIDEN. The objective of this project was to find the most appropriate solution for upgrading sewage sludge in Luxembourg. In 2001, the culmination of the project was the identification of the process of co-composting sewage sludge with structuring organic plant waste (crushed bark and green waste). Soil-Concept aims at reducing direct spreading of sludge on agricultural lands thanks to the spreading of certified compost for soil improvement in agriculture, horticulture and viticulture. The Soil-Concept site has an acceptance capacity of 15 Gg of sludge and 22.5 Gg of green waste. Associated emissions are recorded in IPCC category *5B1* since these are "process" and not "spreading" emissions.

Pre-Treatment of Solid Waste Prior Landfilling

According to the national implementation of the Landfill Directive 1999/31/EC, large streams of waste undergo aerobic treatment procedures prior landfilling. The subcategory *5B1* covers the CH_4 and N_2O emissions generated during the rotting process from waste entering the pre-treatment procedure prior landfilling (see Table 7-8). By doing this, the activity data has been based on the quantity of solid waste from CRF *5A* undergoing the pre-treatment procedures at SIDEC and SIGRE starting from 1993, as reported by the operators.

7.3.2.1.2 Methodology

The IPCC Tier 1 method has been applied to estimate methane and nitrous oxide emissions from compost production as well as pre-treatment of solid waste prior landfilling. CH_4 and N_2O emissions are estimated using the default method given in the following equations:

$$CH_4 emissions = \sum_i (M_i \bullet EF_i) \bullet 10^{-3} - R$$

$$N_2O emissions = \sum_i (M_i \bullet EF_i) \bullet 10^{-3}$$

Where:

CH_4 emissions	=	Total CH_4 emissions in inventory year [Gg CH_4]
N_2O emissions	=	Total N_2O emissions in inventory year [Gg N_2O]
M_i	=	Mass of organic waste treated by biological treatment type i [Gg]
EF_i	=	Emission factor for biological treatment type i
i	=	Composting
R	=	Total amount of CH_4 recovered in inventory year [Gg CH_4][159]

158 http://www.soil-concept.lu

159 So far, emission estimates for composting are *not* taking CH_4 recovery into account.

7.3.2.1.3 Activity Data

Composting

Legal Framework for Composting

Article 19 of the waste legislation of 17 June 1994 stipulates that the management of waste on the territory of the municipalities is under their responsibility. Selective collection of biogenic waste from households is done by means of the green waste bin (currently up to 65.4%) and the majority of municipalities also collect green waste through door-to-door pick-up (currently up to 72.2%). Green waste can also be brought in bulk to municipal and intercommunal collection points, composting facilities or container parks. To date however, not all municipalities offer the collection of organic waste from households.

For the spring season 2017, the Environment Agency is working in collaboration with stakeholders (municipalities, syndicates, operators of interim storage facilities, treatment plants, waste producers) to develop a national network for the collection and recovery of substantial quantities of green waste, including viticulture, forestry and agriculture as well as orchards.

Table 7-16 lists the amount of compostable waste collected from households and commercial activities in Luxembourg, *i.a.* the three main waste syndicates SICA, SIDEC and SIGRE. There has been a drop in compostable waste between 2010 and 2011 due to the installations SICA Mamer and Commune de Hespérange which have not been running in 2011.

The following CED2 waste categories are considered as activity data under *5B1 – Composting*:

CED	*Description*
200108	Separately collected fractions - biodegradable kitchen and canteen waste (except 15 01)
200201	Garden and park waste, biodegradable waste
200302	Other municipal waste – waste from markets

Table 7-16 – Composting Activities: 1993-2015

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
	tonnes wet																						
Total	**5805**	**6745.81**	**8398**	**7354**	**16083**	**26685**	**27729**	**37169**	**34088**	**38424**	**53310.4**	**51692**	**54817**	**57242**	**58196**	**59628**	**63866**	**62202**	**47797.9**	**54108.8**	**55573.64**	**56622.058**	**51163.65**
kg/habitant	*32.31*	*36.93*	*45.31*	*41.95*	*90.48*	*100.24*	*102.81*	*135.75*	*122.24*	*135.22*	*142.00*	*135.94*	*124.91*	*128.20*	*128.37*	*129.57*	*136.14*	*130.35*	*104.69*	*115.73*	*109.01*	*115.84*	*95.76*
Minette-Kompost Mondercange	2904	3629.81	4534	3767	11773	17345	20520	24146	23234	25421	24462	27514	28746	28743	30173	30614	32237	30868	29977.3	32411	33656.3	36222.13	30920.95
kg/habitant	*20.49*	*25.24*	*31.04*	*25.38*	*78.18*	*113.71*	*132.90*	*153.95*	*145.94*	*155.50*	*148.35*	*165.01*	*170.12*	*167.91*	*174.11*	*174.64*	*181.55*	*171.56*	*164.45*	*175.68*	*179.86*	*189.92*	*159.00*
SICA Mamer	2499	2562	3326	3587	4310	3171	3758	4903	4747	4730	4650	4899	5278	5061	5185	5117	5288	5315			2500		
kg/habitant	*98.48*	*98.79*	*126.85*	*133.50*	*158.70*	*115.62*	*135.16*	*176.01*	*168.33*	*167.47*	*164.50*	*171.86*	*182.83*	*172.73*	*174.61*	*169.87*	*172.56*	*171.56*			*77.39*		
SIDEC Fridhaff						6169	3451	8120	5416	5920	6116	6564	6510	6238	6092	5678	5989	5392	5343	6391	6170	6657	6284
SIDEC Angelsberg									691	2353	2174	2534	2651	2670	2702	1917	2219	1784	1815	2491	2343	2549	2146
kg/habitant						*71.5*	*39.4*	*91.1*	*66.8*	*89.5*	*88.7*	*95.9*	*95.1*	*91.1*	*88.4*	*75.1*	*79.8*	*68.6*	*67.0*	*81.2*	*76.2*	*80.6*	*72.3*
Commune de Hespérange											611.4	742	786	743	786	830	743	682	836	862			1 443
kg/habitant											*58.12*	*68.77*	*70.28*	*64.42*	*66.44*	*68.86*	*59.94*	*53.34*	*63.51*	*64.64*			*101.80*
Ville de Luxembourg/ Reckenthal											15297	9439	8083	11108	9733	11921	12187	13767					
kg/habitant											*195.29*	*118.93*	*100.84*	*134.63*	*116.12*	*139.48*	*137.57*	*151.54*					
SIGRE Muertendall													2763	2679	3525	3551	5203	4394	9826.2	11953	10903.51	11193.94	10369.43
kg/habitant													*51.79*	*49.38*	*63.83*	*63.32*	*91.09*	*75.61*	*165.76*	*197.42*	*177.52*	*178.91*	*162.71*
Pétange	402	554	538																				
	tonnes dry																						
Soil-Concept								6379.8	6238.9	8898.1	9488.5	9429.8	10228.1	13401.5	11050.7	14707.1	9827.4	10093.6	10617.5	10889.6	9581.2	9853.9	10531.4

Source: Environment Agency.

Notes: Grey cells indicate that the installation / project has not been running in the given year.

__Pre-Treatment of Solid Waste Prior Landfilling__

At the managed landfill site Fridhaff (managed by SIDEC), waste fractions are distributed within tunnels with forced aeration. The decomposition process takes 6 weeks, with rotations of the material every two weeks. Temperatures are rising to 60 - 70°C during the decomposition of waste.

In contrast, the pre-treatment in Muertendall (managed by SIGRE) is composed of the following steps: crushing, formation of rooting heaps with forced aeration, rotting process, and integration of waste residues into the landfill body. The decomposition lasts for up to 6 months in a 36-ton compactor.

Managed MSW has been multiplied by the fraction being mechanically/biologically treated (Table 7-8, column Mechanical Biological Treatment). From that fraction, inert waste (Table 7-8, column "*Plastics, other inert*") which does not produce emissions has been subtracted. The result, as illustrated in Figure 7-6, shows that a total of 7.02 Gg CO_2e emissions is due to the biological pre-treatment of solid waste prior landfilling (for 2015).

Figure 7-6 – Emissions from Biological Treatment of Solid Waste in *5B1*

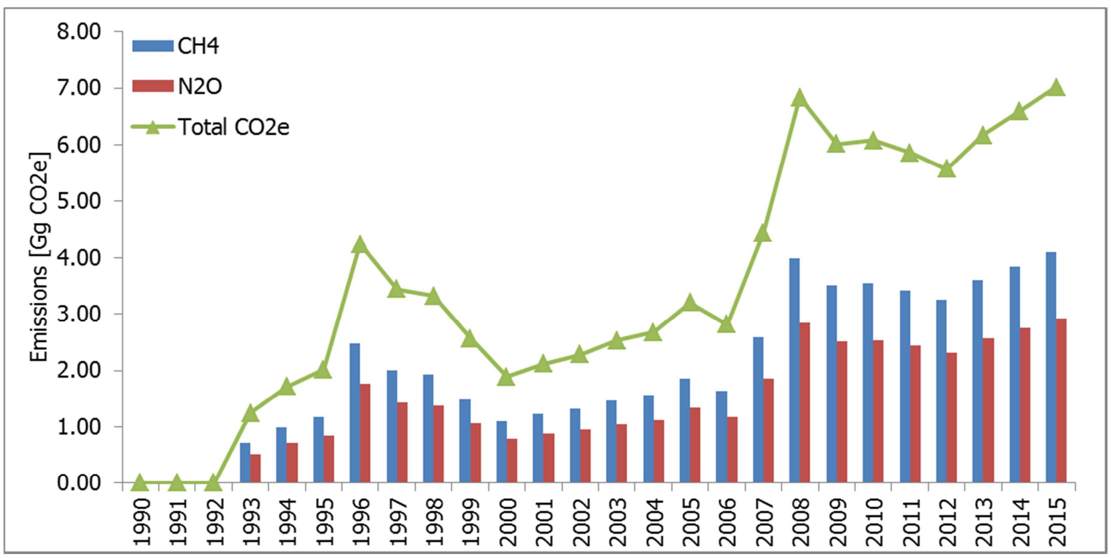

Table 7-17 lists the total emissions from *5B1 – Biogenic Waste Composted at Centralized Composting Plants.*

Table 7-17 – Emissions from *5B1 – Biogenic Waste Composted at Centralized Composting Plants*

5B1 - Biogenic waste composted at centralised composting plants – Emissions (Gg)				
Year	CO_2	CH_4	N_2O	Total in CO_2e
1990	NO	NO	NO	NO
1991	NO	NO	NO	NO
1992	NO	NO	NO	NO
1993	NO	0.05	0.00	2.24
1994	NO	0.07	0.00	2.87
1995	NO	0.08	0.00	3.46
1996	NO	0.13	0.01	5.50
1997	NO	0.14	0.01	6.20
1998	NO	0.18	0.01	7.90
1999	NO	0.17	0.01	7.32
2000	NO	0.26	0.02	11.00
2001	NO	0.25	0.01	10.64
2002	NO	0.30	0.02	12.69
2003	NO	0.37	0.02	15.75
2004	NO	0.36	0.02	15.59
2005	NO	0.40	0.02	16.99
2006	NO	0.43	0.03	18.38
2007	NO	0.45	0.03	19.17
2008	NO	0.54	0.03	23.37
2009	NO	0.49	0.03	21.19
2010	NO	0.49	0.03	21.07
2011	NO	0.43	0.03	18.61
2012	NO	0.46	0.03	19.52
2013	NO	0.46	0.03	19.81
2014	NO	0.48	0.03	20.53
2015	NO	0.47	0.03	20.31
Trend 1993-2015	NA	807.89%	807.89%	807.89%
Trend 2014-2015	NA	-1.10%	-1.10%	-1.10%

Source: Environment Agency.

Note: The added emissions from 2000 onwards are those of the pilot project Soil-Concept.

7.3.2.1.4 Parameters

Emission factors for **compost production** and **biological pre-treatment of solid waste prior landfilling** (Table 7-18) are actually default emission factors for CH_4 and N_2O emissions taken from Table 4.1 in IPCC 2006 Guidelines.

Table 7-18 – Default EFs for CH_4 and N_2O emissions from *5B - Biological Treatment of Waste*

Type of Biological Treatment	CH_4 EF *g CH_4/kg waste treated*	N_2O EF *g N_2O/kg waste treated*	Comment
	on a wet basis		Assumptions on the waste treated: 25-50% DOC in dry matter, 2% N in dry matter, moisture content 60%. EFs for dry waste are estimated from those for wet waste assuming moisture content of 60% in wet waste.
Composting *(excluding Soil-Concept project)*	4 *(0.03 – 8)*	0.24 *(0.06 - 0.6)*	
	on a dry basis		
Soil-Concept project	10 (0.08-20)	0.6 (0.2-1.6)	

7.3.3 Biogenic Waste Treated in Biogas Plants (*5B2*)

7.3.3.1 Methodological Issues

7.3.3.1.1 Data Origin

Luxembourg has only recently put together a preliminary list of anaerobic digestion plants based on the corresponding operating permits from the Environment Agency. While there has only been one facility in service before the year 2000, a total of 21 plants are known to be in service to date.

- Three of the 21 installations feed their cleaned biogas into the local gas distribution system.
- The emissions due to the combustion of biogas (blended or not) are all considered under CRF Sector *1 - Energy*). The national energy balance provides the necessary activity data (biogas production), and also the split in which CRF category the biogas is combusted:
  - *1A1a – Public Electricity and Heat Production*,
  - *1A4a – Commercial / Institutional*, and
  - *1A4c – Agriculture / Forestry / Fishing*.

7.3.3.1.2 Methodology

As the preliminary list of annual reports is incomplete to date, the IPCC methodology has been followed to estimate **CH_4 emissions** from biogas plants due to unintentional leakages, which are assumed to be between 0 and 10% of the amount of CH_4 generated (Volume 5, Chapter 4, Paragraph 4.1, IPCC 2006).

Related to the preliminary analysis, Luxembourg proposes an own estimation starting from the activity data (biogas amounts in Joule, heating value of biogas and CH_4 content in the biogas) available for the category *1 - Energy* to derive a level of CH_4 emissions for the subcategory *5B2 - Biogenic Waste Treated in Biogas Plants* and adapts the method to the collected activity data which derives primarily from agricultural waste and energy plants.

In addition, the average fugitive emission rate has been adapted to 3.1% of the CH_4 gas production rate according to Flesch *et al.* [160]. Comparably, the value of 3% of the CH_4 gas production rate emitted through leakages has been confirmed by the review of Dumont *et al.* [161].

According to the IPCC 2006 Guidelines (Volume 5, Chapter 4, Paragraph 4.1), **N_2O emissions** for *5B2 - Biogenic Waste Treated in Biogas Plants* are assumed to be negligible.

7.3.3.1.3 Activity Data

As mentioned, Luxembourg has only recently put together a preliminary list of anaerobic digestion plants based on the corresponding operating permits. Unfortunately however, the majority of annual reports are missing for the anaerobic digestion plants for the time-series before the year 2007. From a first analysis, one can state the following:

- Biogas production has been reported in the national energy balance starting from the year 1992. The origin of this biogas production is unknown to the Environment Agency as the operating permit of the first anaerobic digestion facility dates back to 1997.
- Three of the 21 installations feed their cleaned biogas into the natural gas network. The regulation of 23 December 2011[162] for conditions ("*Code de distribution*") on how the biogas producers inject the cleaned biogas into the network is applicable. According to Article 12 (2) of this Grand-Ducal Regulation, the biogas producer must document to the Luxembourg Institute of Regulation[163] that CH_4 emissions from the process of treating raw biogas to biogas for injection are less than 0.5% of methane contained in the raw biogas for an amine treatment installation, and less than 1% of the methane contained in the crude biogas for a biogas pressurized treatment plant, respectively.
- The other biogas facilities encounter the emissions due to the combustion of biogas (blended or not) considered under the CRF Sector *1 - Energy*. The national energy balance provides the necessary activity data (biogas production).

The majority of the biogas plants in Luxembourg are modern, *i.e.* 20 out of 21 plants are producing biogas since the year 2000. According to the report of J. Clemens [164], the number of leakages however does not correlate with the number of years in service or the date of the completion of the facility.

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160 Fugitive methane emissions from an agricultural bio-digester (Biomass and Bioenergy Volume 35, Issue 9, October 2011, p. 3927–3935), http://www.sciencedirect.com/science/article/pii/S0961953411003333

161 Methane emissions in biogas production (Pages 248-266 in Chapter 11: The Biogas Handbook – Science, production and applications, 2011)

162 Règlement grand-ducal du 15 décembre 2011 relatif à la production, la rémunération et la commercialisation de biogaz http://www.legilux.public.lu/leg/a/archives/2011/0269/2011A4674A.html

163 https://web.ilr.lu

164 Erfahrungen bei der Untersuchung von Biogasanlagen auf Gasdichtheit (2014) http://www.bonalytic.de/cps/bonalytic/ds_doc/GE_03_2014_Clemens.pdf

Preliminary analysis of the annual reports (available only from 2007 on) shows that the activity data is composed of 18.9% municipal waste, 59.8% agricultural waste, and 21.3% energy plants (Figure 7-7). Relating to these specific activity data, the methane content in the biogas production can vary between 55 to 62% (mean: 58.5%, n = 100) [165] in dependence of the different feedstocks.

Figure 7-7 – Average Feedstock Distribution of Anaerobic Digesters

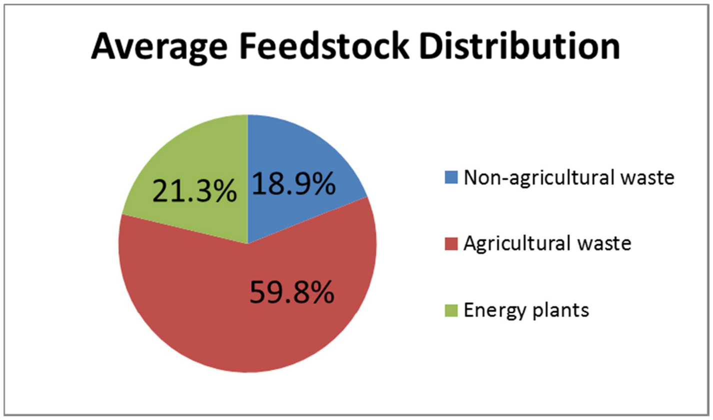


Table 7-19 shows the CH_4 leakage emissions obtained by applying the method adapted to the feedstock distribution as described under *Section 7.3.3.1.2 Methodology*. Annual CH_4 leakage emissions obtained with the IPCC methodology adapted to the national feedstock distribution range from 0.25 Gg CO_2e in 1992 to 8.91 Gg CO_2e in 2015.

165 Biogas production from maize and dairy cattle manure—Influence of biomass composition on the methane yield (2007) (Agriculture, Ecosystems & Environment; Volume 118, Issues 1–4, January 2007, Pages 173–182)

Table 7-19 – CH_4 and N_2O emissions from *5B2 – Biogenic Waste Treated in Biogas Plants*

5B2 - Biogenic Waste Treated in Biogas Plants

Year	Biogas Production (GJ)	Biogas Production (m^3)	CH_4 in biogas produced (m^3)	CH_4 in biogas produced (Gg)	CH_4 leakage (Gg)	N_2O (Gg)	Total in CO_2e (Gg)
1990	NO	NO	NO	NO	NO	NE	NO
1991	NO	NO	NO	NO	NO	NE	NO
1992	17000	776256	454110	0.32	0.01	NE	0.25
1993	17000	776256	454110	0.32	0.01	NE	0.25
1994	17000	776256	454110	0.32	0.01	NE	0.25
1995	19000	867580	507534	0.36	0.01	NE	0.28
1996	19000	867580	507534	0.36	0.01	NE	0.28
1997	15000	684932	400685	0.29	0.01	NE	0.22
1998	12500	570776	333904	0.24	0.01	NE	0.18
1999	10000	456621	267123	0.19	0.01	NE	0.15
2000	44156	2016273	1179520	0.84	0.03	NE	0.65
2001	79624	3635792	2126938	1.52	0.05	NE	1.18
2002	88335	4033583	2359646	1.69	0.05	NE	1.31
2003	147181	6720582	3931540	2.81	0.09	NE	2.18
2004	197942	9038462	5287500	3.78	0.12	NE	2.93
2005	264844	12093349	7074609	5.05	0.16	NE	3.92
2006	317142	14481352	8471591	6.05	0.19	NE	4.69
2007	356019	16256572	9510095	6.79	0.21	NE	5.26
2008	426422	19471328	11390727	8.14	0.25	NE	6.31
2009	518870	23692681	13860218	9.90	0.31	NE	7.67
2010	544445	24860512	14543400	10.39	0.32	NE	8.05
2011	538286	24579271	14378873	10.27	0.32	NE	7.96
2012	563706	25739992	15057895	10.76	0.33	NE	8.34
2013	550812	25151234	14713472	10.51	0.33	NE	8.14
2014	590074	26944012	15762247	11.26	0.35	NE	8.73
2015	602301	27502315	16088854	11.49	0.36	NE	8.91
Trend 1992-2015							3442.95%
Trend 2014-2015							2.07%

Source: Environment Agency.

7.3.3.1.4 Parameters

The following parameters have been used for the estimation of CH_4 leakages based on the IPCC method adapted to national circumstances:

Table 7-20 – Parameters for Estimation of CH_4 Leakages

Parameter	Value	Source
Biogas NCV	0.0219 GJ / m^3	STATEC Table A4200 Supply by type of energy products 1960 - 2014
CH_4 content in biogas	mean: 58.5% (n = 100, ranged from 55 to 62%)	Agriculture, Ecosystems & Environment; Volume 118, Issues 1–4, January 2007, Pages 173–182

Molar mass of CH_4	16 g / mol	
Molar volume of CH_4	0.0224 m^3 / mol	
CH_4 leakage rate	3.1%	Biomass and Bioenergy Volume 35, Issue 9, October 2011, Pages 3927–3935

7.3.4 Uncertainties and Time-Series Consistency

7.3.4.1 Biogenic Waste Composted at Centralised Composting Plants (*5B1*)

The uncertainties for the composted waste quantities are considered very small (< 5 %), since the relevant activity data were obtained *via* high-quality annual reporting. For biological pre-treatment of solid waste prior landfilling, the type, amount and composition of waste are the same as described under CRF *5A*.

The uncertainties for the solid waste quantities undergoing biological treatment are considered the same as in *5A*. As the duration of pre-treatment has an effect on the generation of emissions from waste, the emissions deriving from SIGRE are assumed to be different to the ones deriving from SIDEC. The uncertainties from the literature and from other countries vary between -30 % and +60 % for the CH_4 emission factor (IPCC Guidelines), and at least -50 % and +100 % for the N_2O emission factor (see Table 7-21).

7.3.4.1 Biogenic Waste Treated in Biogas Plants (*5B2*)

To date, activity data for *5B2 - Biogenic Waste Treated in Biogas Plants* is incomplete. Solely, we can assume an uncertainty of ± 6% for the methane content in generated biogas[166], as well as the uncertainty from the energy sector for the activity data. In addition, the uncertainties depend on the type of facility in question, on the type of process used at the relevant time and on the precautions taken to avoid fugitive emissions. All these information are not available at the moment, thus the uncertainties for the *5B2* subsector are assumed to be high (see Table 7-21).

Table 7-21 – Uncertainties with Regard to Activity Data and Emission Factors for CRF *5B*

Uncertainties	Activity data	Emission factor CH_4 [g CH_4 / kg waste treated *]	Emission factor N_2O [g N_2O / kg waste treated *]
5B1 **-** *Biogenic waste composted at centralised composting plants*	± 6.5 % for composting and pretreated solid waste	-30 % to +60 %	-50 % to +100 %

166 Biogas production from maize and dairy cattle manure—Influence of biomass composition on the methane yield (2007) (Agriculture, Ecosystems & Environment; Volume 118, Issues 1–4, January 2007, Pages 173–182)

5B2 **-** *Biogenic waste treated in biogas plants*	see CRF Sector *1 - Energy*	NE	NE

Note: * on a wet weight basis

7.3.5 Category-Specific QA/QC and Verification

No category-specific QA/QC and verification have been completed, only the tools embedded in CRF Reporter have been used.

7.3.6 Category-Specific Recalculations Including Changes Made in Response to the Review Process

Since submission 2016v1, estimated CH_4 and N_2O emissions from aerobic pre-treatment of solid waste have been added to the already estimated emissions from composting activities in *5B1* (Tables 7-22 and 7-23). Also, fugitive CH_4 emissions from unintentional leakages and process disturbances have been added based on activity data from CRF Sector *1 – Energy.*

Table 7-22 – Recalculations with Respect to Previous Submission 2016v1 in Category *5B*

Difference	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Emissions CO_2eq (Gg)	NO	NO	NO	1.50	1.70	1.59	3.59	1.33	0.77	0.57	0.83	1.02	1.12

Difference	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Emissions CO_2eq (Gg)	0.96	1.09	1.22	1.35	1.45	1.90	1.63	1.73	2.24	2.00	2.13	2.06

Table 7-23 – Changes in GHG Inventory since Submission 2016v1

GHG Source & Sink Category	Revisions 2016v1 ➔ 2017v1.2	Type of Revision
5B1 – Emissions	Estimation of fugitive CH_4 and N_2O emissions from the aerobic pre-treatment of solid waste	ARR 2015, §75 ESD 2016
5B2 – Emissions	Preliminary estimation of fugitive CH_4 emissions from unintentional leakages and process disturbances	Decision 24/CP.19; §37b, **2016 LUXQA19**
5B – Uncertainties	Revisited assessment of the sector-specific uncertainty and transfer from the general NIR chapter 1.7 to the sector-specific chapter	ARR 2012

7.3.7 Category-Specific Planned Improvements

7.3.7.1 Biogenic Waste Composted at Centralised Composting Plants (*5B1*)

No planned improvements are foreseen for this subsector.

7.3.7.1 Biogenic Waste Treated in Biogas Plants (*5B2*)

To develop a more specific method to the national situation in the following months, Luxembourg will exactly assess the type of technology installed at the anaerobic digestion plants, the actual methane content of biogas, and the measures taken to prevent unintentional leakages or unexpected disturbances in the process (*i.a.* flaring of CH_4 emissions).

7.4 Incineration and Open Burning of Waste (5C)

This category is presented under IPCC subcategory *1A1a – Fuel Combustion Activities – Energy Industries – Public Electricity and Heat Production* (Section 3.2.6) because in the sole incinerator of the country (SIDOR site), energy from waste burning is recovered and injected into the electric public network.

7.5 Waste Water Treatment and Discharge (5D)

7.5.1 Source Category Description

IPCC Category *5D* covers waste water and related sludge handling, whether these have been generated by households or by industrial enterprises. For the moment, Luxembourg's GHG inventory covers domestic, commercial (Sub-category *5D1*) and industrial (Sub-category *5D2*) waste water handling (WWH), excluding sludge. In addition, it is assumed that domestic and commercial WWH corresponds to municipal waste water treatment carried out in waste water treatment plants (*WWTPs*). CO_2 emissions from municipal WWTP are not included in Luxembourg's GHG inventory for the reason that carbon emissions derive from biomass/biogenic raw materials.

To summarize:

- IPCC Category *5D2* covers nitrous oxide emissions from waste water treatment in industry, thus, emissions from IPCC Category *5D* correspond to emissions deriving from IPCC Sub-category *5D2*; emissions related to methane are not applicable ;
- IPCC Category *5D1* covers methane and nitrous oxide emissions from waste water treatment in residential and commercial sectors and septic tanks. No CO_2 emissions deriving from non-biological or inorganic WWH residuals have been identified so far ;
- Emissions related to the sludge residues of domestic and commercial WWH are not accounted for in this sector. Indeed, sewage sludge spreading is accounted for in the agriculture sector (*3D - Agricultural Soils*), while other parts are incinerated with energy

recovery and the emissions are therefore reported in the energy sector under (*1A2g - Other - Manufacturing Industries and Construction*). The remainder of sludge is composted and emissions are therefore reported under the category other (*5B - Biological Treatment of Solid Waste*), Thus, emissions from IPCC Category *5B* correspond to emissions deriving from IPCC Sub-category *5B2*, excluding sludge.

In 2015, this source category was responsible for 22.89% of the total GHG emissions from the waste sector – excluding waste incineration – and it represented 0.11%of the total GHG emissions in CO_2e (excluding LULUCF). For each of the two gases reported, in 2015:

- CH_4 from WWH represented 10.1% of waste treatment methane related emissions – excluding waste incineration – and 0.56% of the total methane emissions estimated for Luxembourg;
- N_2O from WWH represented 65.5% of waste treatment nitrous oxide related emissions – excluding waste incineration – and almost 2.54% of the total nitrous oxide emissions estimated for Luxembourg.

None of the source categories under WWH is a key category.

7.5.2 Methodological Issues – Methane Emissions

Municipal waste water treatment in Luxembourg uses mainly aerobic processes (see Table 7-24) such as activated sludge or bio-filtration. As a result, no or negligible methane emissions are produced, since such emissions only occur under anaerobic conditions. In these plants, sludge stabilisation is carried out in order to prevent uncontrolled putrefaction. In facilities with a treatment capacity smaller than 30.000 population-equivalents (p. e.) the stabilisation is usually carried out aerobically, with oxygen and energy consumption, while for facilities with a treatment capacity larger than 30.000 p. e., the stabilisation is normally carried out anaerobically with production of methane gas. The gas produced is usually used for energy recovery in combined heat/power generating systems or may be flared.

Table 7-24 shows theoretical load that can be treated in municipal WWTPs since 1990. It also indicates the percentage of that load that is treated using aerobic procedures, *i.e.* in WWTPs applying a biological treatment to waste water.

Table 7-24 – Municipal WWTP capacities and aerobic procedures: 1990-2015

Year	Load treated in municipal WWTP 1000 population-equivalents	Aerobic procedures %
1990	591.6	84%
1991	594	85%
1992	596.5	86%
1993	600	87%
1994	605.8	88%
1995	631.6	89%
1996	782.4	91%
1997	788.4	92%

Year	Load treated in municipal WWTP 1000 population-equivalents	Aerobic procedures %
1998	793.9	92%
1999	799.4	93%
2000	806.9	94%
2001	811.8	94%
2002	816.7	94%
2003	818.7	94%
2004	820.7	95%
2005	820	95%
2006	1012	95%
2007	1016	97%
2008	1017.3	98%
2009	1066.3	98%
2010	1064.7	96%
2011	1014.4	96%
2012	1018.2	96%
2013	1034.9	96%
2014	1036.2	97%
2015	**1015.7**	**97%**
Trend 1990-2015	**80.24%**	**NA**

Source: Water Management Agency

Treatment of human sewage from inhabitants connected to small mechanical treatment facilities or septic tanks represents an exception. The percentage of organic loads discharged to these small treatment units has been reduced consequently since 1990. In this emission inventory, methane emissions from these small anaerobic sludge treatments have been taken into account as there is no gas reuse and therefore methane emissions have been assumed. The methodology for these septic tanks is based on the IPCC method in which the relevant population (individual septic tanks) or population equivalents (for the small mechanical treatment plants) is multiplied by the average organic load *per* person.

The 2006 IPCC default value of 0.6 kg CH_4/kg BOD is used. Each habitant produces 60 g BOD/day, and a MCF of 0.27 is assumed (Steinlechner *et al.* 1994). According to national expert judgment and based on the study of Steinlechner *et al.*, the MCF has been adapted to the national situation in Austria which is also applicable for Luxembourg. The MCF defines the portion of methane producing capacity (B0) that degrades anaerobically and may vary between 0.0 (completely aerobic) to 1.0 (completely anaerobic) according to the IPCC 2006 Guidelines. When the sludge treatment process is anaerobic, the temperature has a great influence. During the winter time, the temperature decreases to 10°C in the sludge digester part of the WWTP so that the biological activity is much reduced and the MCF = 0.1. During the rest of the year the temperature in the sludge part is closer to 20°C which is still low for an optimal biological activity and therefore the MCF factor is 0.35 according to Steinlechner *et al.* As the mechanical waste water treatment plants are based on the same technical process as the septic tanks, the MCF factor used for both categories is the same and is calculated as follows:

$$MCF = 2/3 * 0.35 + 1/3 * 0.1 = 0.27$$

<u>Calculation of the organic load:</u>

*BODsep [kg/year] = inhabitants connected to septic tanks * 60 g BOD (person/day) * 365 (days) / 1000*

*BODmec [kg/year] = inhab. connected to mechanical WWTP * 60 g BOD (person/day) * 365 (days) / 1000*

<u>Calculation of the methane emissions:</u>

*CH_4 sep [t/year] = BODsep * B0 * MCF / 1000 ; where : sep = septic tanks*

*CH_4 mec [t/year] = BODmec * B0 * MCF / 1000*

Where:

mec = mechanical treatment plants

B0 = 0.6 kg CH4/ kg BOD 2006 IPCC Good Practice Guidance (page 6.12)

60 g BOD/person per day: 2006 IPCC Good Practice Guidance (page 6.14) and European Directive 91/271/CEE on the treatment of urbane waste water, Article 2.6

MCF: Methane Conversion Factor (Steinlechner *et al.* (1994): 0.35 * 2/3 + 0.1 * 1/3 = 0.27)

The number of inhabitants connected to a septic tank (sep) is determined annually by the Ministry of Sustainable Development and Infrastructure - Water Management Administration through an inventory. The number of inhabitants from agglomerations connected to a septic tank or to a mechanical treatment plant is based on the last national detailed population inventories. As these censuses take place every ten years, with the most recent one in 2011 the evaluation is based on these population numbers for the years 2011-2013. The new census took place at the beginning of 2011, so that for submission 2014 a recalculation has been done.

<u>Total methane emission from waste water handling:</u>

CH_4 tot = CH_4 sep + CH_4 mec [t/year)]

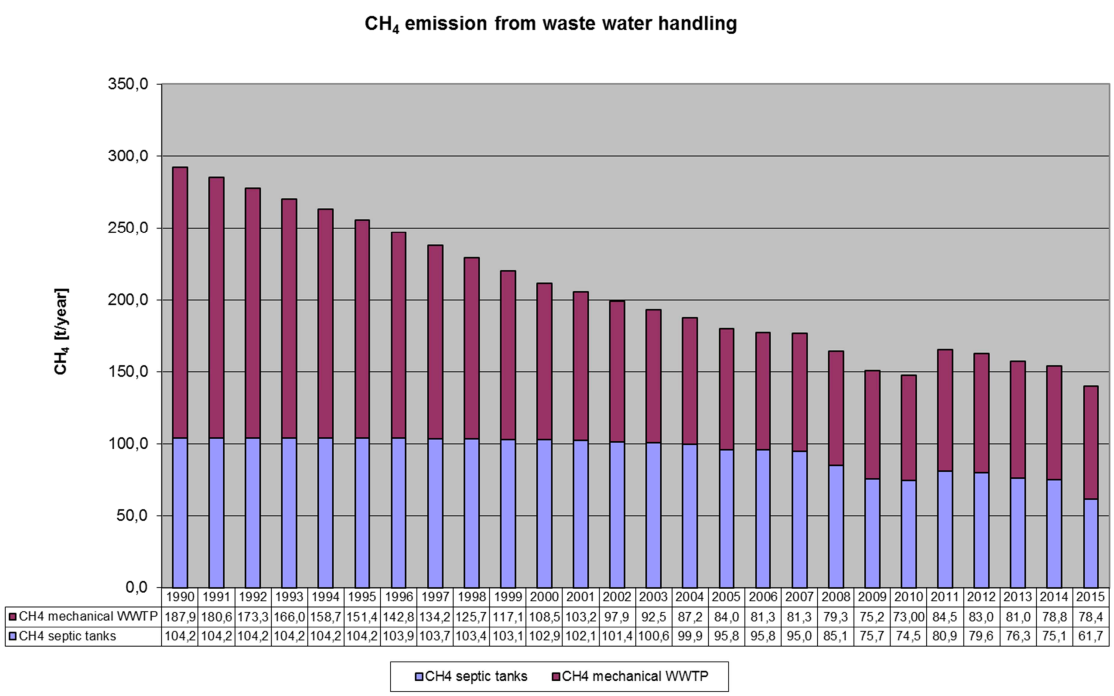
The estimated emissions, obtained following the method described above, are presented in Table 7-25 and Figure 7-8.

Table 7-25 – CH_4 emission trends for IPCC Sub-category *5D1 – Domestic & Commercial WWH*: 1990-2015

CH4 emissions (tonnes)			
5.D.1 Domestic Wastewater			
Year	**Mechanical**	**Septic Tanks**	**Total**
1990	187,94	104,20	292,14
1991	180,63	104,20	284,83
1992	173,33	104,20	277,53
1993	166,02	104,20	270,22
1994	158,72	104,20	262,92
1995	151,41	104,20	255,61
1996	142,83	103,94	246,77
1997	134,25	103,67	237,92
1998	125,66	103,41	229,08
1999	117,08	103,15	220,23
2000	108,50	102,88	211,38
2001	103,18	102,13	205,31
2002	97,86	101,38	199,24
2003	92,54	100,62	193,17
2004	87,23	99,87	187,10
2005	83,98	95,79	179,77
2006	81,27	95,79	177,06
2007	81,27	95,03	176,30
2008	79,25	85,07	164,32
2009	75,20	75,68	150,88
2010	73,00	74,47	147,47
2011	84,46	80,88	165,33
2012	82,96	79,64	162,60
2013	80,96	76,32	157,28
2014	78,81	75,13	153,94
2015	78,37	61,70	140,07
Trend 1990-2015	-58,30%	-40,79%	-52,05%

Source: Water Management Agency.

Figure 7-8 – CH_4 emission trends for category *5D1 – Domestic & Commercial WWH*: 1990-2015



Source: Water Management Agency.

Methane emissions from industrial waste water treatment:

Industrial waste water treatment and sewage sludge treatment is carried out under aerobic conditions (activated sludge process). As for the municipal facilities there are no methane emissions.

7.5.3 Methodological Issues – Nitrous Oxide

7.5.3.1 Nitrous Oxide Emissions from Municipal Waste Water

Pursuant to the 2006 IPCC Guidelines, nitrous oxide emissions from household waste water can be evaluated by taking into account the average per capita protein intake. The IPCC default values are used in each case for the nitrous oxide emission factor per kg of nitrogen in waste water and for the nitrogen fraction in protein.

N_2O emissions from urban waste water handling are calculated by distinguishing waste water arising from populations:

f) not connected to a waste water treatment plant (WWTP)

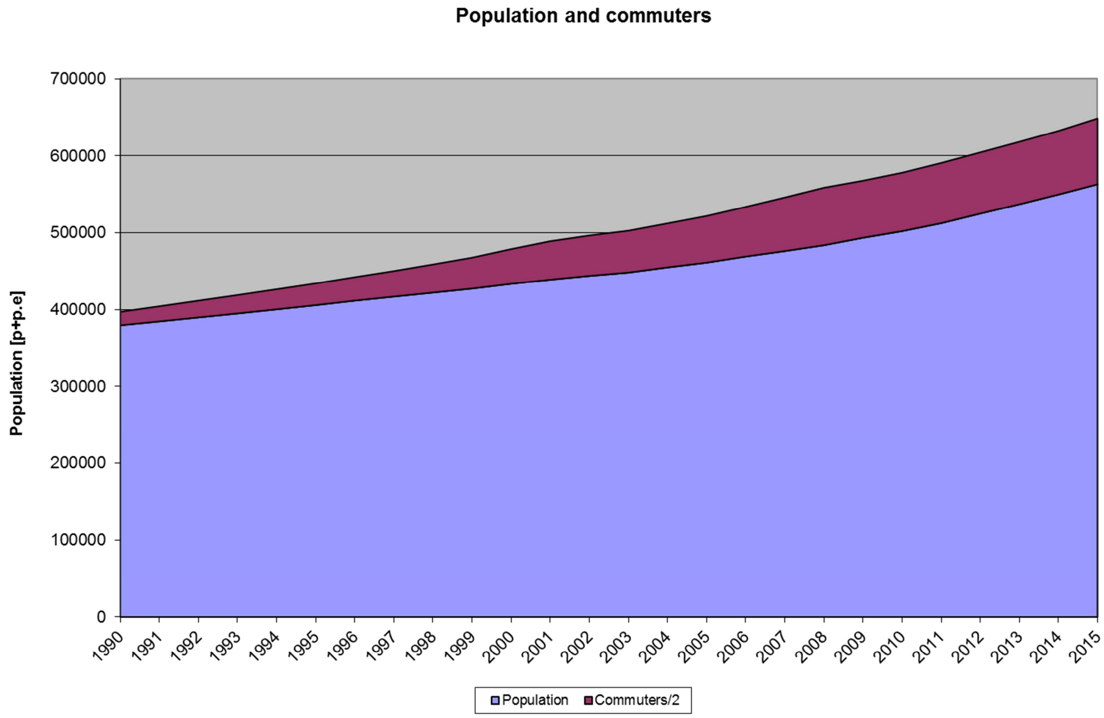
g) connected to a WWTP without denitrification

h) connected to a WWTP with denitrification

The N_2O emissions resulting from the population not connected to a WWTP were calculated according the 2006 IPCC default approach. For the nitrous oxide calculation daily commuters have also been taken into account, in addition to the residents of the country. As these commuters spend only their working hours in the country, their impact was calculated using only half of their nitrous oxide load. The number of inhabitants and the commuters are provided by the STATEC.

Figure 7-9 illustrates the population and cross-border commuters' growth between 1990 and 2015. The latter is divided by 2 in the figure below (so that only a half load of nitrogen is counted for by commuting individual).

Figure 7-9 – Resident population and cross-border commuters: 1990-2015



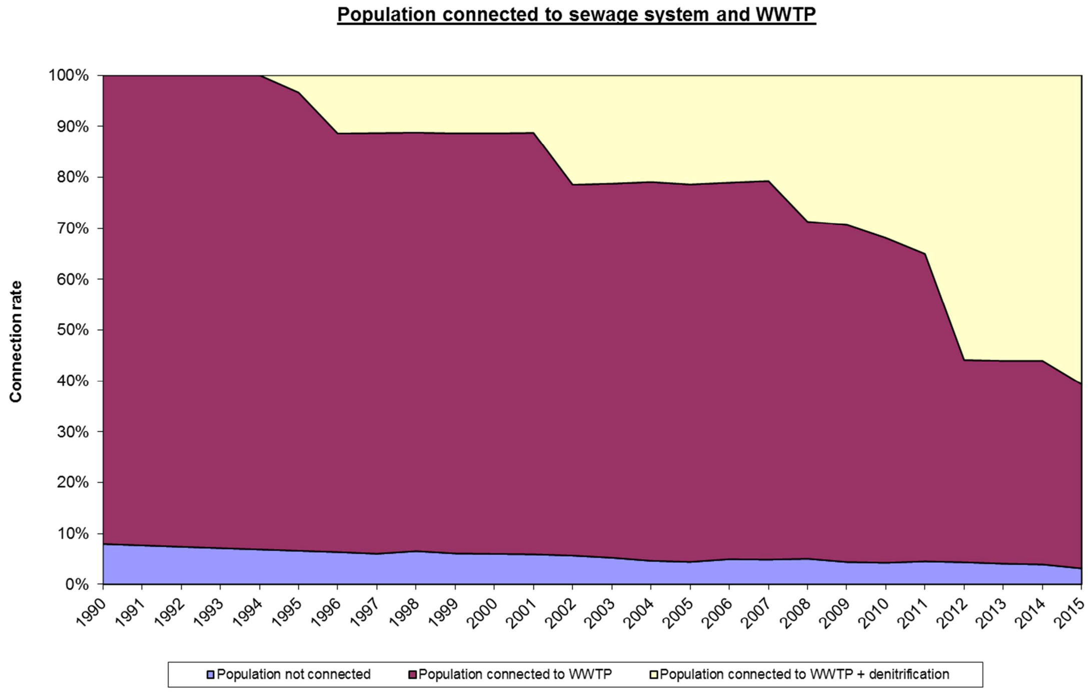
Sources: Le Portail des Statistiques au Luxembourg, *Statistical Yearbook,*
http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=383&IF_Language=fra&MainTheme=2&FldrName=1&RFPath=68
http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=494&IF_Language=fra&MainTheme=2&FldrName=3&RFPath=92

Denitrification is a treatment requirement in Luxembourg for Urban Waste Water Treatment Plants based on the European Directive 91/271/CEE concerning urban waste water treatment. WWTP with an organic design capacity larger than 10 000 population-equivalents (p. e.) have to meet the minimum reduction rate of 75% of total nitrogen. The objective of denitrification is to reduce the risk of eutrophication of surface waters.

For the current evaluation of the N_2O emissions the methodology of the 2006 IPCC Guidelines has been applied with a default value 3.2 g N_2O per capita per year (for biological waste water treatment plant with denitrification processes) as well a factor of Find-com of 1.25 based on data in Metcalf & Eddy (2003) and expert judgment.

Figure 7-10 provides an overview of the population of Luxembourg connected to WWTPs (with or without denitrification) or not. In 2014, the number of the population connected to WWTPs with denitrification increased considerably due to the fact that 3 new WTTPs with denitrification went online. Consequently, N_2O emissions were reduced accordingly.

Figure 7-10 – Population connected to sewage system and biological WWTP: 1990-2015



Source: Water Management Agency.

Determination of N_2O from waste water not connected to a biological WWTP (2006 IPCC Guidelines):

$$N_2O\ nc\ [t/year] = N\ effluent * F\ ind\text{-}com * EF\ effluent / 1000 * 44/28$$

Where:

nc = not connected

N effluent = P * Protein * F NPR

with P = inhabitants (p. e.) not connected

Protein = protein intake per person (kg/year) (http://www.fao.org)

EF effluent = Emission Factor 0.005 (2006 IPCC Guidelines default value, page 6.25)

F ind-com = fraction of industrial and commercial co-discharged protein (default = 1.25, based on data in Metcalf & Eddy (2003) and expert judgment; IPCC Guidelines, page 6.26)

F NPR = 0.16 kg N/kg protein (2006 IPCC Guidelines, page 6.25)

44/28 = 1.57: conversion of N_2O-N to N_2O (44/28, N_2O/N))

Determination of N_2O from waste water connected to a biological WWTP without denitrification:

$$N_2Owwtp\ [t/year] = N\ effluent / 1000 * \%\ FRAC\ denitri * 0.01 * F\ ind\text{-}com * 44/28$$

Where:

WWTP = waste water treatment plant

N effluent = P * Protein * F NPR

with P = population connected

Protein = protein intake per person (kg/year) (http://www.fao.org)

F NPR = 0.16 kg N/kg protein (2006 IPCC Guidelines, page 6.25)

% FRAC denitri = 35 % denitrification rate (% of waste water which is denitrified)

0.01: 1% of the denitrified N is emitted as N2O (ORTHOFER *et al.* 1995)

F ind-com = fraction of industrial and commercial co-discharged protein (default = 1.25, based on data in Metcalf & Eddy (2003) and expert judgment, IPCC Guidelines, page 6.26)

44/28 = 1.57, conversion of N_2O-N to N_2O (44/28, N_2O/N)

<u>Determination of N_2O from waste water connected to a biological WWTP with denitrification:</u>

$$N_2Owwtp\text{-}de = P * F\ ind\text{-}com * EF\ plant / 1.000.000 \qquad [t/year]$$

Where:

wwtp-de = waste water treatment plant with denitrification

P = inhabitants connected

F ind-com = fraction of industrial and commercial co-discharged protein (default = 1.25, based on data in Metcalf & Eddy (2003) and expert judgment; IPCC Guidelines, page 6.26)

EF plant = emission factor, 3.2 g N_2O / person / year

<u>Determination of N_2O total emission from waste water handling:</u>

$$N_2Omun\ tot\ [t/year] = N_2O\ not\ connected + N_2O\ connected\ to\ WWTP\ without\ denitrification + N_2O\ connected\ to\ WWTP\ with\ denitrification$$

Where:

mun = municipal waste water

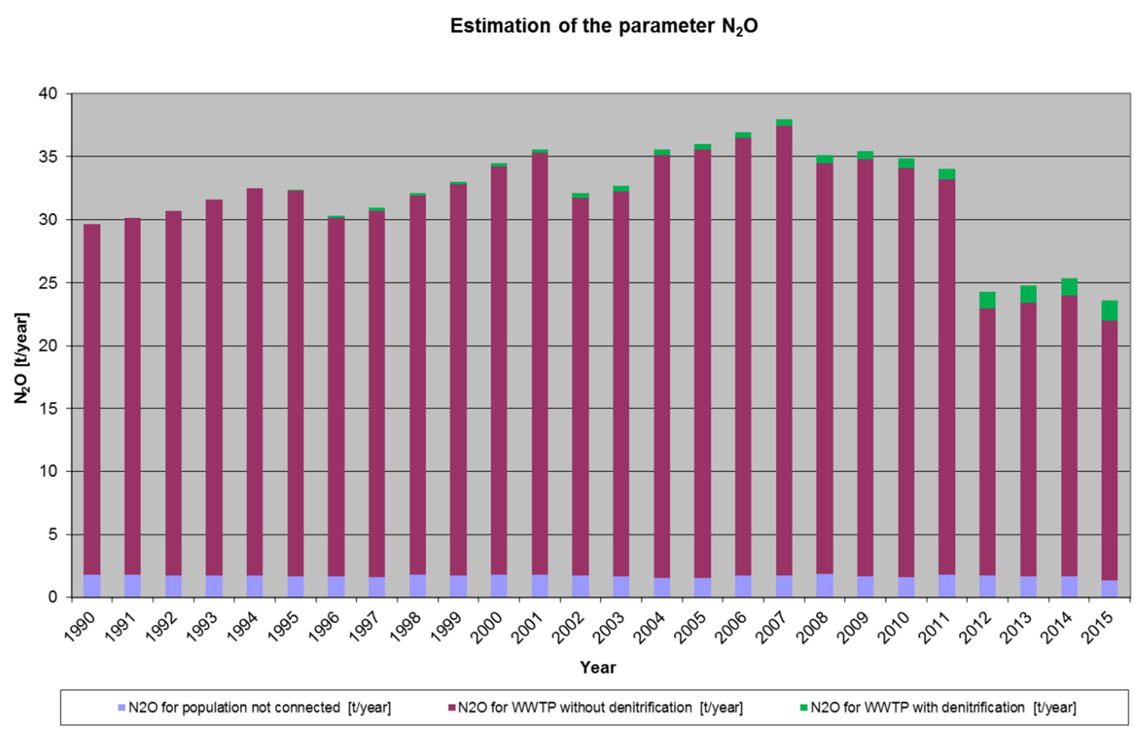
The estimated emissions obtained following the method described above are presented in Table 7-26 and Figure 7-11.

Table 7-26 – N_2O emission trends for category *5D1 – Domestic & Commercial WWH*: 1990-2015

	N_2O emissions (tonnes)			
	5.D.1 Domestic Wastewater			
Year	**N_2O nc**	**N_2O wwtp**	**N_2O wwtp-de**	**Total**
1990	1,84	27,78	NO	29,61
1991	1,80	28,37	NO	30,17
1992	1,77	28,97	NO	30,74
1993	1,75	29,87	NO	31,62
1994	1,74	30,79	NO	32,52
1995	1,72	30,58	NO	32,30
1996	1,68	28,47	NO	30,15
1997	1,62	29,12	0,20	30,95
1998	1,83	30,09	0,21	32,13
1999	1,75	31,07	0,21	33,04
2000	1,80	32,43	0,22	34,45
2001	1,83	33,50	0,22	35,55
2002	1,78	29,94	0,43	32,14
2003	1,67	30,57	0,43	32,67
2004	1,60	33,53	0,43	35,55
2005	1,55	34,04	0,45	36,04
2006	1,78	34,72	0,45	36,95
2007	1,79	35,71	0,45	37,95
2008	1,90	32,56	0,64	35,09
2009	1,68	33,11	0,66	35,45
2010	1,65	32,47	0,74	34,86
2011	1,80	31,41	0,83	34,03
2012	1,77	21,16	1,35	24,28
2013	1,70	21,69	1,39	24,77
2014	1,67	22,28	1,42	25,36
2015	1,37	20,66	1,57	23,60
Trend 1990-2015	-25,26%	-25,64%	672%	-20,30%

Source: Water Management Agency.

Figure 7-11 – N_2O emission trends for category *5D1 – Domestic & Commercial WWH*: 1990-2015



Source: Water Management Agency.

7.5.3.2 Nitrous Oxide Emissions from Industrial WWTP

N_2O emissions from industrial waste water handling are issued from two industrial plants, the first one produces plastics and from 2015 a second one that produces milk products. Both release N to aquatic environments. These industrial waste water treatment plants (WWTP) are equipped with a biological treatment with denitrification. N_2O emissions are based on the measured inflow data in the WWTP. The data available since the year 2002 are the flow as well as the mean annual nitrogen concentration in the WWTP.

The determination of N_2O from waste water connected to an industrial waste water treatment plant with denitrification is calculated as follows:

$$N_2O\ ind = N\ cc\ [mg/l] * Inflow\ [m3/a] /1000 * \%\ FRAC\ denitri * 0.01 * 44/28 \quad [t/year]$$

Where:

ind = industrial

N cc = N concentration in mg/l (measured data)

Inflow = flow in m^3/year (measured data)

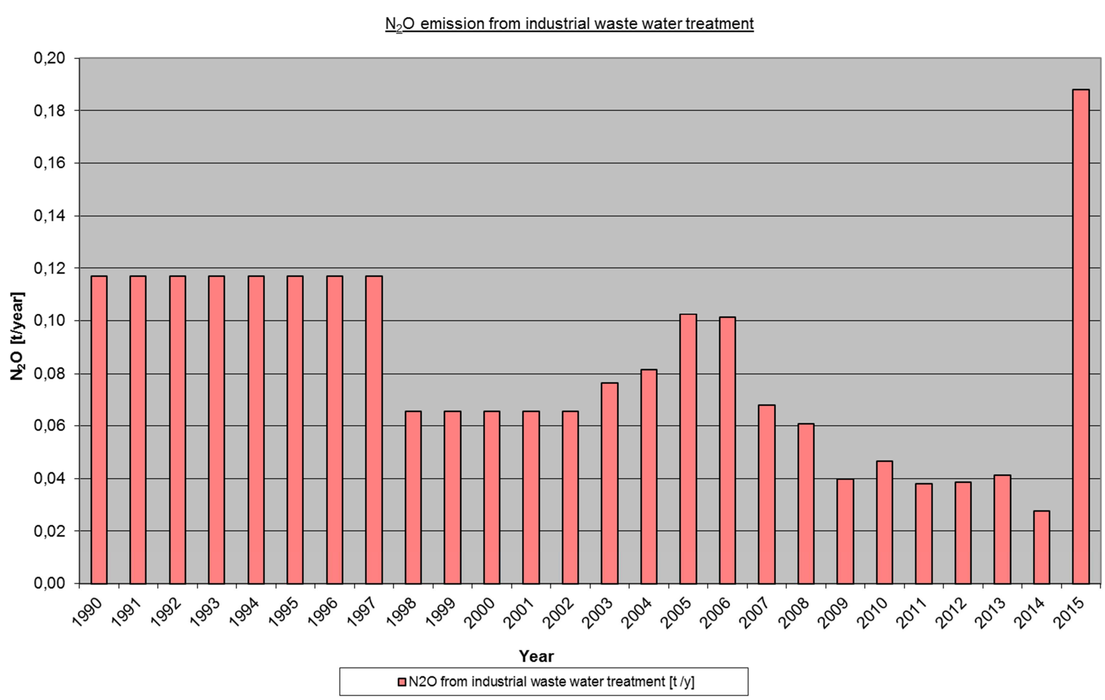
% FRAC denitri = 70% denitrification rate in % (% of waste water which is denitrified)

0.01 = 1% of the denitrified N is emitted as N_2O (ORTHOFER *et al.* 1995)

44/28 = 1.57, conversion of N_2O-N to N_2O (44/28, N_2O/N)

The estimated emissions obtained following the method described above are presented in Figure 7-12.

Figure 7-12 – N_2O emission trends for category *5D2 – Industrial Waste Water WWH*: 1990-2015



Source: Water Management Agency.

Determination of N concentration:

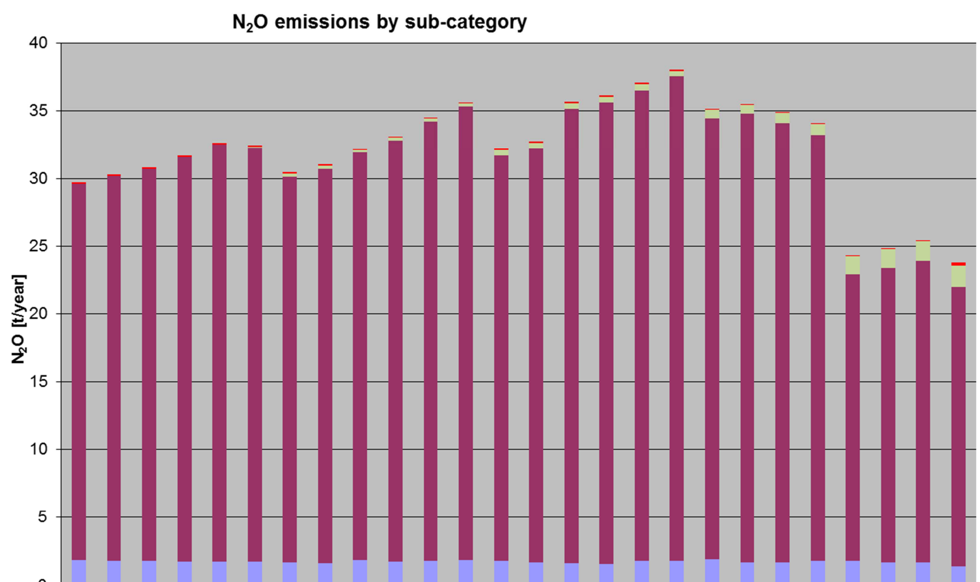
Year 1990 - 1997	Year 1998 - 2002	Year 2002 – 2014	Year 2015
N concentration extrapolated by expert judgment of the water management administration	N concentration extrapolated by expert judgment of the water management administration. In 1998 the WWTP has been upgraded allowing also denitrification	N concentration based on monitoring analyses	N concentration based on monitoring analyses (for both industrial plants)

7.5.3.3 Determination of the Total Nitrous Oxide Emissions

$$N_2O\ tot = N_2O\ mun\ tot + N_2O\ ind$$

The estimated emissions obtained following the formula described above are presented in Figure 7-13 and Table 7-27.

Figure 7-13 - N_2O emission trends for category 5D1 and category 5D2 WWH: 1990-2015



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
N2O from industrial waste water treatment [t /y]	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,07	0,07	0,07	0,07	0,07	0,08	0,08	0,10	0,10	0,07	0,06	0,04	0,05	0,04	0,04	0,04	0,03	0,19
N2O for WWTP with denitrification [t/year]	0,00	0,00	0,00	0,00	0,00	0,06	0,20	0,20	0,21	0,21	0,22	0,22	0,43	0,43	0,43	0,45	0,45	0,45	0,64	0,66	0,74	0,83	1,35	1,39	1,42	1,57
N2O for WWTP without denitrification [t/year]	27,8	28,4	29,0	29,9	30,8	30,6	28,5	29,1	30,1	31,1	32,4	33,5	29,9	30,6	33,5	34,0	34,7	35,7	32,6	33,1	32,5	31,4	21,2	21,7	22,3	20,7
N2O for population not connected [t/year]	1,84	1,80	1,77	1,75	1,74	1,72	1,68	1,62	1,83	1,75	1,80	1,83	1,78	1,67	1,60	1,55	1,78	1,79	1,90	1,68	1,65	1,80	1,77	1,70	1,67	1,37

Year

Source: Water Management Agency.

Table 7-27 – N_2O emission trends for category *5D1* and category *5D2* WWH: 1990-2015

	N2O emissions (tonnes)				
	5.D.1 Domestic Wastewater & 5.D.2 Industrial Wastewater				
Year	**N_2O nc**	**N_2O wwtp**	**N_2O wwtp-de**	**N_2O ind**	**Total**
1990	1,84	27,78	NO	0,12	29,73
1991	1,80	28,37	NO	0,12	30,29
1992	1,77	28,97	NO	0,12	30,86
1993	1,75	29,87	NO	0,12	31,74
1994	1,74	30,79	NO	0,12	32,64
1995	1,72	30,58	0,06	0,12	32,47
1996	1,68	28,47	0,20	0,12	30,47
1997	1,62	29,12	0,20	0,12	31,07
1998	1,83	30,09	0,21	0,07	32,19
1999	1,75	31,07	0,21	0,07	33,10
2000	1,80	32,43	0,22	0,07	34,51
2001	1,83	33,50	0,22	0,07	35,62
2002	1,78	29,94	0,43	0,07	32,21
2003	1,67	30,57	0,43	0,08	32,74
2004	1,60	33,53	0,43	0,08	35,64
2005	1,55	34,04	0,45	0,10	36,14
2006	1,78	34,72	0,45	0,10	37,05
2007	1,79	35,71	0,45	0,07	38,02
2008	1,90	32,56	0,64	0,06	35,15
2009	1,68	33,11	0,66	0,04	35,49
2010	1,65	32,47	0,74	0,05	34,91
2011	1,80	31,41	0,83	0,04	34,07
2012	1,77	21,16	1,35	0,04	24,31
2013	1,70	21,69	1,39	0,04	24,81
2014	1,67	22,28	1,42	0,03	25,39
2015	1,37	20,66	1,57	0,19	23,79
Trend 1990-2015	-25,26%	-25,64%	2576%	61%	-19,98%

Source: Water Management Agency.

7.5.4 Uncertainties and Time-Series Consistency

- Waste water quantity: 10 % not connected to waste water treatment plants
- Emission factor for N_2O: 50% (IPCC 2006 - Guidelines)
- Emission factor for CH_4: 50%

  (Treatment of uncertainties for national estimates of GHG Emission, Charles D., 1998, referenced by Wilfried Winiwarter)

For further information on uncertainties, please refer to Section 1.7.

7.5.5 Category-Specific QA/QC and Verification

Category-specific QA/QC procedures have been completed for the following parameters:

1) Activity data:

- Population and commuters from the STATEC (national data inventory of Luxemburg);
- Number and size of WWTP from national inventory from the Water Management Administration;

- Measured data for the denitrification efficiency;

2) Parameters and emission factor:

- References are indicated, waste expert (QA);

3) Emissions:

- References are indicated, waste expert (QA).

7.5.6 Category-specific recalculations including changes have been made in response to the review process

Table 7-28 presents the main revisions and recalculations done relevant to CRF category *5D1*.

Table 7-28 - Changes in GHG inventory since submission 2016v1

GHG source & sink category	Revisions 2016v1➔ 2017v1.2	Type of revision
5D1	No recalculations operated.	NA

7.5.7 Category-Specific Planned Improvements

Taking into account the potential contribution of identified improvements in the total GHG emissions and the corresponding resources needed to make these improvements effective, developments presented in Table 7-29 will be explored.

Table 7-29 – Planned improvements for IPCC Category 5D1 – WWH

GHG source & sink category	Planned improvement
5D1 – Domestic & Commercial WWH – CH_4	List of WWTPs which produce methane gas for energy reuse in combined heat/power generating systems
5D1 – Domestic & Commercial WWH	Reassessment of the EF_{plant} for WWTP with and without denitrification following comments from ERT. Ongoing study with the Umweltbundesamt Austria

8 Other

CRF Sector 6 is not applicable to Luxembourg's inventory.

9 Indirect CO_2 and nitrous oxide emissions[167]

No indirect CO_2 and nitrous oxide emissions have been reported.

[167] Content of this chapter should be consistent with paragraph 29. In addition, Annex I Parties should provide information on the following precursor gases: carbon monoxide (CO), nitrogen oxides (NOX) and non-methane volatile organic compounds (NMVOCs), as well as sulphur oxides (SOX). Annex I Parties may report indirect CO2 from the atmospheric oxidation of CH4, CO and NMVOCs. Annex I Parties may report as a memo item indirect N2O emissions from other than the agriculture and LULUCF sources. These estimates of indirect N2O should not be included in national totals. For Parties that decide to report indirect CO2 the national totals shall be presented with and without indirect CO2.

10 Recalculations and Improvements

Table 10-1 summarises the main revisions and recalculations done since the last submission. More details can be found in the respective sector chapters.

Table 10-1 – Revisions and recalculations done since submission 2016v1

GHG source & sink category	Revisions 2016v1 ➔ 2017v1.2	Type of revision
Reference approach	AD was revised according to the revised energy balance and IEA Questionnaires as provided by STATEC	updated AD
Reference approach	Other fossil fuels: added CO2 emission from other fossil fuels, as estimated for category 1A2f to the reference approach, as national energy balance does not include the consumption of these fuels.	Added fuel type
Reference approach	All parameters and carbon contents were revised, if necessary, according to the 2006 IPPC Guidelines.	updated parameters
International Bunkers - Aviation	The CO2 emission factor for aviation gasoline was corrected from 69300 kg/TJ to 70000 kg/TJ.	Changed CO2 EF
1A1a	Natural gas consumption in 1A1a for the year 2014 was revised in the national energy balance.	Updated AD
1A1a	Two transcription errors affecting the emissions from MSW in 1.A.1.a – Public Electricity and Heat Production in 1991 and 2013 have been corrected.	updated AD
1A1a	An adjustment of the total MSW in the Grand-Duchy (as explained in more detail in section 0) impacts the emissions for the timeseries 2001-2014, as the calorific fraction is deducted from SIDOR's MSW to avoid double counting.	updated AD
1A2	Fuel consumption data for natural gas, gasoil and diesel oil was revised due to revised energy balance from the national statistics institute	updated AD
1A1a	waste incineration with energy recovery: implemented new waste composition analysis from 2013/14	updated AD
1A2	Major revisions in the energy balance have been done for natural gas allocated to the categories 1.A.2 – Manufacturing industries and construction and 1.A.4 – Other sectors for the years 2000-2014.	Updated AD
1A2gvii	Activity data has been updated according to a recent study[168].	Updated AD
1A2gvii	The country-specific CO2 emission factor for motor gasoline was changed from a fixed value of 72'000 kg CO_2/TJ to a country-specific emission factor based on a weighted average of the EFs of the countries from where motor gasoline is imported for the entire time-series. See text below for details.	Changed CO_2 EF for gasoline
1A3a	The CO_2 EF was corrected from 69300 to 70000 kg/TJ (IPCC 2006 Guidelines default value).	updated CO_2 EF
1A3b	Activity data were revised according to a new study[169].	updated AD
1A3b, 1A3d	Updated CO_2 EF for gasoline according to a recommendation from the ERT during the centralised UNFCCC review in September 2016.The ERT recommended that Luxembourg switches back to the previous approach where a country-specific CO_2 emission factor for gasoline is determined according to the quantities of gasoline imported from the different countries and the respective emission factors used by these countries. This approach is used in this submission for the entire time-series, in all sub-categories to which gasoline is allocated (1A2gvii, 1A3b, 1A3d, 1A4b).	updated CO_2 EF
1A4a	AD for gasoil, natural gas and biomass was revised due to a revised energy balance by the national statistics institute.	Updated AD

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168 Komobile, FVT: Aktualisierung der Zeitreihen zum Kraftstoff-export und der Emissionen von klimarelevanten Gasen und Luftschadstoffen des Verkehrssektors in Luxemburg von 1990 - 2015, Endbericht, 2017, Graz, Luxemburg

169 Komobile, FVT: Aktualisierung der Zeitreihen zum Kraftstoff-export und der Emissionen von klimarelevanten Gasen und Luftschadstoffen des Verkehrssektors in Luxemburg von 1990 - 2015, Endbericht, 2017, Graz, Luxemburg

GHG source & sink category	Revisions 2016v1 ➔ 2017v1.2	Type of revision
1A4b, 1A4c	AD for mobile machinery were updated according to a new study[170].	Updated AD
1A4b, 1A4c	Updated CO_2 EF for gasoline according to a recommendation from the ERT during the centralised UNFCCC review in September 2016.The ERT recommended that Luxembourg switches back to the previous approach where a country-specific CO_2 emission factor for gasoline is determined according to the quantities of gasoline imported from the different countries and the respective emission factors used by these countries. This approach is used in this submission for the entire time-series, in all sub-categories to which gasoline is allocated (1A2gvii, 1A3b, 1A3d, 1A4b).	Changed CO_2 EF for gasoline
1A5b	Activity data for 1A5b has been revides based on a new study[171]. Until submission 2016v1 the activity data reported in this sub-category corresponded to fuel consumptions allocated to "Other – including military, and non-attributable consumption" in the national energy balance. However, activity data was only available from 1992 to 1999. In submission 2017v1.2, activity data reported under 1A5b corresponds only to fuel consumption estimated for military vehicles for the entire time-series.	Updated AD
1A5b	The method used for estimating CH_4 and N_2O emissions from 1A5b is based on the GEORG model which conforms to the requirements of the IPCC 2006 GL Tier 3 methodology.	CH_4 and N_2O methodology and EFs
2A1	The value for CO2 emissions for the year 2014 has been revaluated.	Methodology
2A3	For the years 2005-2014, EFs were revaluated.	Changed EF
2D3.1	update of: data of production statistics, import and export statistics update of emission factors and solvent content update of plant specific, information from associations of industries and statistical data for "general aspects" and "specific aspects" .	updated AD and EF
2D3.2	Based on a new study (Komobile, FTV, 2017), activity data for the years 2005-2014 has been revised.	Updated AD
2F1	Emission estimates have been revised for the entire time series, and are now taking into account emissions from the entire fleet of refrigerated vehicles.	Updated AD
2F2	The PU spray emissions (HFC 134a, HFC 152a) and the extruded polystyrene (XPS) emissions (HFC 134a) are estimated using the reported quantities used per habitant and year in Belgium, which have been updated.	Updated AD
2F4	data for 2013 and 2014 were incorrect and have been replaced by correct values	Error correction
2G3a	Previously extrapolated data for 2013 and 2014 was replaced by updated data.	Updated AD
4 - LULUCF areas	Data of land use changes between forestland and wetland for the time series between 1990-1999 were revised	Revised AD
4 - LULUCF areas	Data of land use changes between perennial cropland and grassland for the time series between 1990-1999 were revised	Revised AD
4 - LULUCF areas	Data of land use changes between grassland and cropland were extracted from the LPIS database for the years 2009-2015.	Revised AD
4 – LULUCF	Calculation of indirect N2O emissions for Nitrogen leaching related to direct N2O emissions from nitrogen mineralisation associated with loss of soil organic matter resulting from change of land.	Calculation of N2O emission LU-4-2017-0002
4 – LULUCF	A comprehensive uncertainty and time series consistency analysis was carried out for the LULUCF sector.	Revision of uncertainties ARR 2014, §60
4 - LULUCF	N2O emissions (direct and leached emission) associated with loss of soil carbon were calculated for all land use changes (previously only those associated with cropland were	LU-3D-2016-0001

[170] Komobile, FVT: Aktualisierung der Zeitreihen zum Kraftstoff-export und der Emissionen von klimarelevanten Gasen und Luftschadstoffen des Verkehrssektors in Luxemburg von 1990 - 2015, Endbericht, 2017, Graz, Luxemburg

[171] Komobile, FVT: Aktualisierung der Zeitreihen zum Kraftstoff-export und der Emissionen von klimarelevanten Gasen und Luftschadstoffen des Verkehrssektors in Luxemburg von 1990 - 2015, Endbericht, 2017, Graz, Luxemburg

GHG source & sink category	Revisions 2016v1 ➔ 2017v1.2	Type of revision
	calculated).	
5A	The waste generation rate per capita is based on STATEC data adjusted to the quantities of the annual reports according to Chapter 7.2.2.1	Updated AD
5A	The validity of the methane correction factor has been assessed for the national circumstances and was changed from 0.1 to 1. The landfill receiving pre-treated waste residues is not classified anymore as an uncategorized landfill. Independently on whether waste is (i) landfilled directly or (ii) pre-treated at SIGRE (since 1993) or SIDEC (since 2007), the MCF of 1 is applicable to managed anaerobic landfills.	Updated MCF ARR 2014 ARR 2015, §75
5A	Emissions from the deposition of pre-treated residues is now reported under 5A for the year 1993 onwards, except for emissions from rotting process (reported under 5B1)	Improved transparency ARR 2013, §69
5A	Methane recovery from solid waste disposal on land was changed for the year 2000	Updated emissions ARR 2013, §70
5A	The values of the methane oxidation factor OX have been adapted according to the waste disposal and the introduction of pre-treatment of solid waste	ARR 2012, §104 CF 2014
5A	Revisited assessment of the sector-specific uncertainty and transfer from the general NIR chapter 1.7 to the sector-specific chapter	ARR 2012 CR 2014
5B1	Estimation of fugitive CH4 and N2O emissions from the aerobic pre-treatment of solid waste	ARR 2015, §75 ESD 2016
5B2	Preliminary estimation of fugitive CH4 emissions from unintentional leakages and process disturbances	Decision 24/CP.19; §37b, 2016 LUXQA19
5B	Revisited assessment of the sector-specific uncertainty and transfer from the general NIR chapter 1.7 to the sector-specific chapter	ARR 2012

Table 10-2, Table 10-3, Table 10-4 and Table 10-5 present the recalculations of CO_2, CH_4, N_2O and total GHG emissions for the years 1990, 1995, 2000, 2005 and 2010-2014.

Table 10-2 – CO_2 emissions: recalculations done since submission 2016v1

CO_2								
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Base year (1990)	2000	2005	2010	2011	2012	2013	2014
	(Gg)	(Gg)	(Gg)	(Gg)	(Gg)	(Gg)	(Gg)	(Gg)
1. Energy	**-140.97**	**-142.06**	**-102.46**	**-110.84**	**-91.59**	**-65.89**	**-44.27**	**-42.93**
A. Fuel Combustion (Sectoral Approach)	-140.97	-142.06	-102.46	-110.84	-91.59	-65.89	-44.27	-42.93
1. Energy Industries	-	0.00	-0.76	-1.22	1.15	3.28	-0.01	-53.05
2. Manufacturing Industries and Construction	-37.69	-57.67	-175.75	-145.42	-121.47	-55.02	-28.75	58.45
3. Transport	-101.83	-16.14	156.75	109.57	80.44	39.34	43.00	21.12
4. Other Sectors	21.96	-68.37	-82.82	-73.89	-51.84	-53.61	-58.63	-69.56
5. Other	-23.41	0.12	0.12	0.12	0.12	0.12	0.12	0.12
B. Fugitive Emissions from Fuels	-	-	-	-	-	-	-	-
1. Solid Fuels	NO	NO	NO	NO	NO	NO	NO	NO
2. Oil and natural gas and other emissions from ene	-	-	-	-	-	-	-	-
C. CO2 transport and storage	NO	NO	NO	NO	NO	NO	NO	NO
2. Industrial Processes	**-8.49**	**-3.89**	**-3.08**	**1.48**	**0.13**	**-0.09**	**5.71**	**10.16**
A. Mineral industry	-	-	-1.19	0.99	-0.76	-1.63	0.50	8.13
B. Chemical industry	NO	NO	NO	NO	NO	NO	NO	NO
C. Metal industry	-	-	-	-	-	-	-	-
D. Non-energy products from fuels and solvent use	-8.49	-3.89	-1.89	0.49	0.89	1.54	5.20	2.03
E. Electronic industry								
F. Product uses as ODS substitutes								
G. Other product manufacture and use	NO	NO	NO	NO	NO	NO	NO	NO
H. Other	NO	NO	NO	NO	NO	NO	NO	NO
3. Agriculture	-	-	-	-	-	-	-	-
A. Enteric fermentation								
B. Manure management								
C. Rice cultivation								
D. Agricultural soils								
E. Prescribed burning of savannas								
F. Field burning of agricultural residues								
G. Liming	-	-	-	-	-	-	-	-
H. Urea application	NE	NE	NE	NE	NE	NE	NE	NE
I. Other carbon-containing fertilizers	NO	NO	NO	NO	NO	NO	NO	NO
J. Other	NO	NO	NO	NO	NO	NO	NO	NO
4. Land use, land-use change and forestry (2)	**-20.50**	**-16.60**	**-12.36**	**-13.01**	**-12.58**	**-9.95**	**-9.05**	**-7.05**
A. Forest land	-0.53	-	-	-	-	-	-	-
B. Cropland	-3.69	-	-	5.60	6.54	8.38	9.25	10.34
C. Grassland	-17.42	-16.15	-11.78	-15.42	-15.89	-15.08	-15.03	-14.09
D. Wetlands	1.13	0.47	0.35	0.22	0.20	0.17	0.15	0.12
E. Settlements	-	-0.93	-0.93	-3.43	-3.43	-3.43	-3.43	-3.43
F. Other land	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G. Harvested wood products	NO	NO	NO	NO	NO	NO	NO	NO
H. Other	NO	NO	NO	NO	NO	NO	NO	NO
5. Waste	**NA,NO,IE**	**NA,NO,IE**	**NA,NO,IE**	**NA,NO,IE**	**NA,NO,IE**	**NA,NO,IE**	**NA,NO,IE**	**NA,NO,IE**
A. Solid waste disposal	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO
B. Biological treatment of solid waste								
C. Incineration and open burning of waste	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	NO,IE
D. Waste water treatment and discharge								
E. Other	NO	NO	NO	NO	NO	NO	NO	NO
6. Other (as specified in summary 1.A)	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Memo items:	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
International bunkers	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aviation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Navigation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Multilateral operations	NO	NO	NO	NO	NO	NO	NO	NO
CO_2 emissions from biomass	0.00	0.41	-0.71	-3.21	-14.37	-7.42	-21.46	-11.67
CO_2 captured	NO	NO	NO	NO	NO	NO	NO	NO
Long-term storage of C in waste disposal sites	NE	NE	NE	NE	NE	NE	NE	NE
Indirect N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 10-3 – CH_4 emissions: recalculations done since submission 2016v1

CH_4								
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Base year (1990) (Gg)	2000 (Gg)	2005 (Gg)	2010 (Gg)	2011 (Gg)	2012 (Gg)	2013 (Gg)	2014 (Gg)
1. Energy	**-0.03**	**-0.08**	**-0.05**	**-0.03**	**-0.03**	**-0.02**	**-0.05**	**-0.04**
A. Fuel combustion (sectoral approach)	-0.03	-0.08	-0.05	-0.03	-0.03	-0.02	-0.05	-0.04
1. Energy industries	-	-	0.00	0.00	0.00	0.00	0.00	0.00
2. Manufacturing industries and construction	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00
3. Transport	-0.03	-0.07	-0.04	-0.02	-0.02	-0.02	-0.02	-0.04
4. Other sectors	0.01	-0.01	0.00	0.00	0.00	0.00	-0.03	0.00
5. Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B. Fugitive emissions from fuels	-	-	-	-	-	-	-	-
1. Solid fuels	NO	NO	NO	NO	NO	NO	NO	NO
2. Oil and natural gas and other emissions from ene	-	-	-	-	-	-	-	-
C. CO2 transport and storage								
2. Industrial processes	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
A. Mineral industry								
B. Chemical industry	NO	NO	NO	NO	NO	NO	NO	NO
C. Metal industry	NO	NO	NO	NO	NO	NO	NO	NO
D. Non-energy products from fuels and solvent use	NO	NO	NO	NO	NO	NO	NO	NO
E. Electronic industry								
F. Product uses as ODS substitutes								
G. Other product manufacture and use	NO	NO	NO	NO	NO	NO	NO	NO
H. Other	NO	NO	NO	NO	NO	NO	NO	NO
3. Agriculture	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.13**
A. Enteric fermentation	-	-	-	-	-	-	-	0.11
B. Manure management	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
C. Rice cultivation	NO	NO	NO	NO	NO	NO	NO	NO
D. Agricultural soils	NO	NO	NO	NO	NO	NO	NO	NO
E. Prescribed burning of savannas	NO	NO	NO	NO	NO	NO	NO	NO
F. Field burning of agricultural residues	NO	NO	NO	NO	NO	NO	NO	NO
G. Liming								
H. Urea application								
I. Other carbon-containing fertilizers								
J. Other	NO	NO	NO	NO	NO	NO	NO	NO
4. Land use, land-use change and forestry (2)	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
A. Forest land	NO	NO	NO	NO	NO	NO	NO	NO
B. Cropland	NO	NO	NO	NO	NO	NO	NO	NO
C. Grassland	NO	NO	NO	NO	NO	NO	NO	NO
D. Wetlands	NO	NO	NO	NO	NO	NO	NO	NO
E. Settlements	NO	NO	NO	NO	NO	NO	NO	NO
F. Other land	NO	NO	NO	NO	NO	NO	NO	NO
G. Harvested wood products								
H. Other	NO	NO	NO	NO	NO	NO	NO	NO
5. Waste	**0.63**	**0.94**	**1.45**	**1.46**	**1.53**	**1.58**	**1.63**	**1.69**
A. Solid waste disposal	0.63	0.81	1.11	0.90	0.97	1.01	1.05	1.09
B. Biological treatment of solid waste	NO,IE	0.13	0.33	0.56	0.56	0.57	0.58	0.61
C. Incineration and open burning of waste	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	NO,IE
D. Waste water treatment and discharge	-	-	-	-	-	-	-	-
E. Other	NO	NO	NO	NO	NO	NO	NO	NO
6. Other (as specified in summary 1.A)	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Total CH_4 emissions without CH_4 from LULUCF	**0.61**	**0.86**	**1.40**	**1.43**	**1.50**	**1.56**	**1.58**	**1.79**
Total CH_4 emissions with CH_4 from LULUCF	**0.61**	**0.86**	**1.40**	**1.43**	**1.50**	**1.56**	**1.58**	**1.79**

Table 10-4 – N_2O emissions: recalculations done since submission 2016v1

N_2O								
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Base year (1990) (Gg)	2000 (Gg)	2005 (Gg)	2010 (Gg)	2011 (Gg)	2012 (Gg)	2013 (Gg)	2014 (Gg)
1. Energy	-0.02	-0.01	-0.06	-0.01	0.00	0.00	0.00	0.00
A. Fuel combustion (sectoral approach)	-0.02	-0.01	-0.06	-0.01	0.00	0.00	0.00	0.00
1. Energy industries	-	-	0.00	0.00	0.00	0.00	0.00	0.00
2. Manufacturing industries and construction	-0.01	0.01	-0.05	-0.01	-0.01	0.00	0.00	0.00
3. Transport	0.00	-0.01	0.00	0.01	0.01	0.01	0.01	0.01
4. Other sectors	0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
5. Other	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B. Fugitive emissions from fuels	NO	NO	NO	NO	NO	NO	NO	NO
1. Solid fuels	NO	NO	NO	NO	NO	NO	NO	NO
2. Oil and natural gas and other emissions from ene	NO	NO	NO	NO	NO	NO	NO	NO
C. CO2 transport and storage								
2. Industrial processes	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**-0.08**
A. Mineral industry								
B. Chemical industry	NO	NO	NO	NO	NO	NO	NO	NO
C. Metal industry	NO	NO	NO	NO	NO	NO	NO	NO
D. Non-energy products from fuels and solvent use	NO	NO	NO	NO	NO	NO	NO	NO
E. Electronic industry								
F. Product uses as ODS substitutes								
G. Other product manufacture and use	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.08
H. Other	NO	NO	NO	NO	NO	NO	NO	NO
3. Agriculture	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**-0.03**
A. Enteric fermentation								
B. Manure management	-	-	-	-	-	-	-	0.00
C. Rice cultivation								
D. Agricultural soils	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.03
E. Prescribed burning of savannas	NO	NO	NO	NO	NO	NO	NO	NO
F. Field burning of agricultural residues	NO	NO	NO	NO	NO	NO	NO	NO
G. Liming								
H. Urea application								
I. Other carbon-containing fertilizers								
J. Other	NO	NO	NO	NO	NO	NO	NO	NO
4. Land use, land-use change and forestry (2)	**0.06**	**0.06**	**0.05**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**
A. Forest land	NO	NO	NO	NO	NO	NO	NO	NO
B. Cropland	-	-	-	0.00	0.00	0.00	0.00	0.00
D. Wetlands	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E. Settlements	0.04	0.04	0.03	0.03	0.03	0.03	0.02	0.02
F. Other land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G. Harvested wood products								
H. Other	NO	NO	NO	NO	NO	NO	NO	NO
5. Waste	**-**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.02**	**0.02**
A. Solid waste disposal								
B. Biological treatment of solid waste	NA,NO	0.01	0.01	0.01	0.01	0.01	0.02	0.02
C. Incineration and open burning of waste	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	NO,IE
D. Waste water treatment and discharge	-	-	-	-	-	-	-	-
E. Other	NO	NO	NO	NO	NO	NO	NO	NO
6. Other (as specified in summary 1.A)	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Total direct N_2O emissions without N_2O from LULUCF	**-0.02**	**-0.01**	**-0.05**	**0.00**	**0.01**	**0.01**	**0.01**	**-0.09**
Total direct N_2O emissions with N_2O from LULUCF	**0.04**	**0.05**	**0.00**	**0.05**	**0.05**	**0.05**	**0.05**	**-0.05**

Table 10-5 – Total GHG emissions: recalculations done since submission 2016v1

CO_2 equivalents								
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Base year (1990)	2000	2005	2010	2011	2012	2013	2014
CO_2 equivalents	(Gg)	(Gg)	(Gg)	(Gg)	(Gg)	(Gg)	(Gg)	(Gg)
1. Energy	**-147.31**	**-147.11**	**-120.39**	**-113.72**	**-91.89**	**-65.83**	**-44.91**	**-43.38**
A. Fuel combustion (sectoral approach)	-147.31	-147.11	-120.39	-113.72	-91.89	-65.83	-44.91	-43.38
1. Energy industries	0.00	0.00	-0.79	-1.33	1.05	3.23	-0.21	-52.90
2. Manufacturing industries and construction	-41.44	-56.21	-189.86	-149.14	-123.10	-55.21	-28.46	59.58
3. Transport	-103.59	-20.11	155.78	113.46	83.77	41.51	45.42	21.65
4. Other sectors	23.85	-70.92	-85.65	-76.83	-53.73	-55.47	-61.78	-71.84
5. Other	-26.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13
B. Fugitive emissions from fuels	0.00	-	0.00	-	-	0.00	-	-
1. Solid fuels	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2. Oil and natural gas and other emissions from ene	0.00	-	0.00	-	-	0.00	-	-
C. CO2 transport and storage	NO	NO	NO	NO	NO	NO	NO	NO
2. Industrial processes	**-8.21**	**-2.98**	**-1.94**	**2.99**	**1.66**	**1.50**	**7.27**	**-12.70**
A. Mineral industry	-	-	-1.19	0.99	-0.76	-1.63	0.50	8.13
B. Chemical industry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C. Metal industry	-	-	-	-	-	-	-	-
D. Non-energy products from fuels and solvent use	-8.49	-3.89	-1.89	0.49	0.89	1.54	5.20	2.03
E. Electronic industry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F. Product uses as ODS substitutes	-	0.60	0.80	1.13	1.15	1.20	1.19	1.05
G. Other product manufacture and use	0.28	0.32	0.34	0.37	0.38	0.39	0.37	-23.91
H. Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3. Agriculture	**-0.81**	**-0.98**	**-1.28**	**-1.36**	**-1.39**	**-1.46**	**-1.41**	**-5.39**
A. Enteric fermentation	-	-	-	-	0.00	-	0.00	2.82
B. Manure management	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.52
C. Rice cultivation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D. Agricultural soils	-0.81	-0.98	-1.28	-1.36	-1.39	-1.46	-1.41	-8.73
E. Prescribed burning of savannas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F. Field burning of agricultural residues	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G. Liming	-	-	-	-	-	-	-	-
H. Urea application	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I. Other carbon-containing fertilizers	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
J. Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4. Land use, land-use change and forestry (2)	**-7.71**	**-4.02**	**-0.81**	**-2.95**	**-2.87**	**-0.56**	**-0.03**	**1.61**
A. Forest land	-0.53	-	-	-	-	-	-	-
B. Cropland	-3.69	-	-	6.01	7.08	9.10	10.10	11.31
C. Grassland	-16.42	-15.19	-11.02	-14.88	-15.40	-14.64	-14.63	-13.74
D. Wetlands	2.24	1.56	1.35	1.04	0.96	0.88	0.80	0.72
E. Settlements	10.60	9.52	8.79	4.84	4.45	4.06	3.67	3.28
F. Other land	0.09	0.09	0.07	0.05	0.04	0.04	0.03	0.03
G. Harvested wood products	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H. Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5. Waste	**15.84**	**25.41**	**39.36**	**40.87**	**42.63**	**43.79**	**45.38**	**46.86**
A. Solid waste disposal	15.84	20.13	27.86	22.42	24.26	25.21	26.36	27.15
B. Biological treatment of solid waste	0.00	5.28	11.50	18.46	18.37	18.58	19.02	19.71
C. Incineration and open burning of waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D. Waste water treatment and discharge	-	-	0.00	-	-	0.00	-	-
E. Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6. Other (as specified in summary 1.A)	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Memo items:								
International bunkers	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aviation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Navigation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Multilateral operations	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO_2 emissions from biomass	0.00	0.41	-0.71	-3.21	-14.37	-7.42	-21.46	-11.67
CO_2 captured								
Long-term storage of C in waste disposal sites								
Indirect N_2O								
Total CO_2 equivalent emissions without land use, land-	**-140.49**	**-125.65**	**-84.25**	**-71.23**	**-49.00**	**-21.99**	**6.34**	**-14.61**
Total CO_2 equivalent emissions with land use, land-use	**-148.20**	**-129.67**	**-85.07**	**-74.19**	**-51.86**	**-22.55**	**6.31**	**-13.01**
Total CO_2 equivalent emissions, including indirect CO_2,	**-140.49**	**-125.65**	**-84.25**	**-71.23**	**-49.00**	**-21.99**	**6.34**	**-14.61**

Table 10-6 presents the recalculation differences of national total GHG emissions (excl. LULUCF) for 1990-2014 in Gg CO_2eq and in %.

Table 10-6 - Recalculation difference of national total GHG emissions (without LULUCF).

	total GHG emissions excl. LULUCF			
	submission 2017v1	submission 2016v1.01	recalculation difference	recalculation difference
year	Gg CO_2eq	Gg CO_2eq	Gg CO_2eq	%
1990	12730.46	12870.95	-140.49	-1.09%
1991	13366.69	13416.64	-49.96	-0.37%
1992	13120.17	13192.78	-72.61	-0.55%
1993	13255.94	13309.33	-53.38	-0.40%
1994	12419.85	12476.91	-57.06	-0.46%
1995	10049.92	10089.23	-39.31	-0.39%
1996	10108.35	10160.56	-52.21	-0.51%
1997	9461.25	9476.40	-15.15	-0.16%
1998	8578.56	8565.82	12.73	0.15%
1999	9039.99	8935.33	104.66	1.17%
2000	9616.97	9742.63	-125.65	-1.29%
2001	10102.92	10245.40	-142.49	-1.39%
2002	10881.78	11006.87	-125.10	-1.14%
2003	11324.32	11366.81	-42.49	-0.37%
2004	12717.16	12809.52	-92.36	-0.72%
2005	12961.17	13045.43	-84.25	-0.65%
2006	12798.04	12898.80	-100.76	-0.78%
2007	12225.34	12313.97	-88.63	-0.72%
2008	12111.83	12168.84	-57.01	-0.47%
2009	11573.37	11649.91	-76.53	-0.66%
2010	12149.97	12221.20	-71.23	-0.58%
2011	12042.45	12091.45	-49.00	-0.41%
2012	11749.85	11771.84	-21.99	-0.19%
2013	11213.64	11207.30	6.34	0.06%
2014	10755.97	10770.58	-14.61	-0.14%

Table 10-7 summarises the planned improvements.

Table 10-7– Planned improvements

GHG source & sink category	Planned improvements
Reference approach	Provide a quantitative estimate of each separate discrepancy between RA and SA as outlined in Section 3.2.1.2.
Reference approach	Improve consistency between the reference and sectoral approaches: fuel consumption of international bunkers - marine need to be subtracted from the reference approach where it is still included (ARR 2013, §22).
International Bunkers - Aviation	Analyse LTO data per aircraft type from Eurostat for Luxembourg in order to optimize split between International Bunkers – Aviation and 1A3a – Domestic aviation.
1A4a, 1A4b	collecting information helping to refine the fuel consumption split between the commercial/institutional sectors, on the one hand, and the residential sector, on the other hand.
1B2a5	Assess whether these emissions occur and, if appropriate, estimate and report fugitive emissions from the infrastructure supporting the transport, distribution, storage and sale of refined fuel oils.
2D2	Obtaining country specific data for the years 1990 to 1998
2F2, 2F4	Continue the quest for country-specific data
3D	SER will try to improve and complete the time series of maize production in crop production activity data.
3G	A limestone inventory having limestone vendors as data sources is envisaged to enhance future quality of data
4A	Luxembourg plans to revise its OBS maps by 2018-2019
5A	To obtain the exact DOC value of pre-treated waste residues and validate the estimations in Table 7-8, material is planned to be analysed in the framework of a research project.

11 KP-LULUCF

11.1 General information

11.1.1 Definition of forest

The LU89, LU99, LU07 and LU12 land use maps are the main data providers for the greenhouse gas reporting of IPCC category forestland. The National Forest Inventory (NFI) of Luxembourg is the main data provider for the development of carbon stock factors. Consequently, and for reason of consistency, the applied forest definition for the reporting follows the definition used within the IFN and the LU maps. The selected parameters are:

Land Use Class	Definition
ForestLand	All forest and wooded land according to the FAO TBRA2000 definition: • Minimum land area: 0.5 ha • Minimum crown cover: 10 % • Minimum height:5 m. In the geodata set, Forest land has been sub-divided into the forest types as defined below.
Conifers:	Including all forest land with > 10 % crown cover and on which more than 75 percent of the tree crown cover consists of coniferous species.
Deciduous:	Including all forest land with > 10 % crown cover and on which more than 75 percent of the tree crown cover consists of broadleaved species
Mixed (coniferous and deciduous):	with > 10 % crown cover and less than 75 % crown cover of one class.

Permanently unstocked basal areas, which are directly connected with forest in terms of space and forestry enterprise and contribute directly to its management (such as forestal hauling systems, wood storage places, forest glades, forest roads), also represent forests. Areas which are used in short rotation with a rotation period of up to thirty years as well as forest arboretums, forest seed orchards, Christmas tree plantations and plantations of woody plants for the purpose of obtaining fruits such as walnut or sweet chestnut do not account as forests but represent cropland. Rows of trees (except shelter belts for wind protection) and areas with woody plants in a park structure are not forest land.

Areas are assigned to the activities "afforestation" and "deforestation" if they have been afforested or deforested since 1.1.1990. Such areas remain in those assigned categories until the end of the commitment period. As a result, the areas of said categories increase constantly.

In general, reforestation requirements apply in Luxembourg, meaning that clear-cut forest areas and thinned forest stands have to be reforested or replenished and continue to fall into forest and do not represent AR events. Forest areas that have temporarily no forest cover as a result of natural disturbances, continue to fall within the definition of forest and must be reforested. No deforestation as a result of natural disturbances takes place in Luxembourg.

11.1.2 Elected activities under Article 3.4

As reported in the Initial Report, Luxembourg has decided, during the first commitment period, not to elect any of the activities under Article 3.4 of the Kyoto Protocol. According to Article 3 (4) of the Kyoto Protocol Luxembourg has to carry out accounting for its forestry activities (forest management) in the second commitment period. Due to a lack of reliable data Luxembourg is reporting emissions from harvested wood products as instantaneous oxidation. Furthermore Luxembourg has elected the option natural disturbances but not the provision for carbon equivalent forests.

Figure 11-1 – Activity coverage relating to activities under Art. 3.3 and 3.4 (CRF table NIR-1)

Activity	CHANGE IN CARBON POOL REPORTED[1]							GREENHOUSE GAS SOURCES REPORTED[2]							
	Above-ground biomass	Below-ground biomass	Litter	Dead wood	Soil		HWP[4]	Fertilization[5]	Drained, rewetted and other soils[6]		Nitrogen mineralization in mineral soils[8]	Indirect N_2O emissions from managed soil[5]	Biomass burning[9]		
					Mineral	Organic[3]		N_2O	CH_4[7]	N_2O	N_2O	N_2O	CO_2[10]	CH_4	N_2O
Article 3.3 activities															
Afforestation and reforestation	R	R	R	R	R	NO	IO	NO	NO	NO	NO	NO	NO	NO	NO
Deforestation	R	R	R	R	R	NO	IO	NO	NO	NO	R	NO	NO	NO	NO
Article 3.4 activities															
Forest management	R	R	R	R	R	NO	IO	NO	NO	NO	NO	NO	NO	NO	NO
Cropland management	NR	NR	NR	NR	NR	NO			NO		NA		NO	NO	NO
Grazing land management	NR	NR	NR	NR	NR	NO			NO		NA		NO	NO	NO
Revegetation	NR	NR	NR	NR	NR	NO		NO	NO	NO	NO	NO	NO	NO	NO
Wetland drainage and rewetting	NR	NR	NR	NR		NO		NO	NO	NO		NO	NO	NO	NO

11.1.3 Description of how the definitions of each activity under Article 3.3 have been implemented and applied consistently over time

11.1.3.1 Afforestation, reforestation and deforestation (ARD)

The area of forest land reported for Afforestation/Reforestation (AR) and Deforestation (D) under the Kyoto Protocol is based on the area reported for Land use changes from and to forests in the UNFCCC greenhouse gas inventory by taking the different time frame (ARD areas starting with 1.1.1990) as well as the permanence of ARD areas into account.

In other words, annual areas from Annual Cropland converted to Forestland, Perennial Cropland converted to Forestland, Grassland converted to Forestland, Wetlands converted to Forestland, Settlements converted to Forestland, Other land converted to Forestland are summed and considered as AR. And reciprocally, Forestland converted to Annual Cropland, Perennial Cropland, Grassland, Wetland, Settlements and Other land are considered as D.

Afforestation is defined as "the direct human-induced conversion of land that has not been forested for a period of at 50 years to forested land through planting, seeding and/or the human-induced promotion of natural seed sources." Reforestation differs from afforestation solely with regard to the time since the area was last forested and occurs on land that has not been forest since 31 December 1989. Since the reporting period for Luxembourg begins with base year 1990, and since adequate data for differentiation of land-use forms are available only for the period as of 1989, afforestation and reforestation are considered together in the present context (and hereafter are both referred to as afforestation).

Table 11-1 Areas of LUC from and to forests and ARD areas since 1990

	Forest management	Art. 3.3 D areas since 1990	Art. 3.3 AR areas since 1990	*4A1. Forest land remaining forest land followed for 20 years*	*LULUCF - LUC to Forest followed for 20 years*
1990	92.62	0.00	0.00	79.31	14.00
1991	92.18	-0.44	0.70	79.57	14.00
1992	91.73	-0.88	1.40	79.83	14.00
1993	91.29	-1.32	2.10	80.09	14.00
1994	90.85	-1.77	2.80	80.35	14.00
1995	90.41	-2.21	3.50	80.61	14.00
1996	89.97	-2.65	4.20	80.87	14.00
1997	89.53	-3.09	4.90	81.12	14.00
1998	89.08	-3.53	5.60	81.38	14.00
1999	88.64	-3.97	6.30	81.64	14.00
2000	88.52	-4.42	7.00	82.21	13.48
2001	88.39	-4.55	7.18	82.79	12.96
2002	88.26	-4.69	7.36	83.36	12.43
2003	88.13	-4.83	7.53	83.93	11.91
2004	88.01	-4.96	7.71	84.50	11.39
2005	87.88	-5.10	7.89	85.08	10.86
2006	87.75	-5.23	8.06	85.65	10.34
2007	87.62	-5.37	8.24	86.22	9.82
2008	87.58	-5.51	8.42	86.88	9.17
2009	87.54	-5.55	8.47	87.54	8.52
2010	87.50	-5.59	8.52	88.20	7.88
2011	87.47	-5.62	8.58	88.87	7.23
2012	87.43	-5.66	8.63	89.53	6.58
2013	87.39	-5.70	8.68	90.19	5.93
2014	87.35	-5.74	8.73	90.85	5.29
2015	87.31	-5.78	8.79	91.51	4.64

Table 11-1 provides an overview of the areas as they are followed under both methodologies. FM, AR and D are determined according to the activity based accounting as defined under KP. The categories forestland remaining forestland and LUC to forest are calculated under the land based accounting method as defined under the rules of UNFCCC.

11.1.3.2 Forest management (FM)

In Luxembourg, all forest areas that have been forest since 1990 are considered managed within the meaning of the Marrakesh Accords and are reported under forest management according to Art. 3.4 KP.

The areas considered under forest management in KP are different from the forest areas considered under the UNFCCC category “forest land remaining forest land”. Under KP land use changes to forest are reported under ARD and remain in that category. Under UNFCC calculations land-use changes to forest land are, after a period of 20 years, reported under the category "forest land remaining forest land". Under UNFCCC land use changes are also considered that occurred before 1990. Areas that have been converted to forest land between 1970 and 1990 are subsequently reported under forest management under KP but under LUC to forest land under UNFCCC for a transition period of 20 years. As a consequence the area of the category "forest land remaining forest land" under UNFCC is higher than the area of the category forest management for the period 1990-2010 and smaller for the period after 2010. The area of forest management equals at each year the sum of forest land remaining forest land and LUC area to forest (total forest area) minus afforestation area since 1.1.1990.

Due to unreliable and incomplete data on harvested wood products in Luxembourg, the emissions contribution from harvested wood products in Luxembourg, are considered as instantaneous oxidation.

11.1.3.3 Cropland management (CM)

Luxembourg has not elected CM.

11.1.3.4 Grazing land management (GM)

Luxembourg has not elected GM.

11.1.3.5 Description of precedence conditions and/or hierarchy among Article 3.4 activities, how they have been consistently applied in determining how land was classified

Luxembourg has defined the hierarchy of activities relative to Art. 3.4 of the Kyoto Protocol according to the provisions of the IPCC KP Supplement (2014). The activity forest management is binding, and thus has priority over the voluntary activities cropland management and grazing land management. In the first commitment period, Luxembourg did not elect forest management voluntarily. The hierarchy makes it possible to carry out consistent reporting for the first and second commitment periods.

According to the provisions of the IPCC KP Supplements (2014), forest management (FM) can take place only on lands that meet the definition of forest. The forest areas reported under FM are the forest areas reported, likewise to the Convention, under forest land remaining forest land, plus the areas assigned to the categories of LUC to forest land (Convention) minus the areas of the category of af-/reforestation (Kyoto Protocol). The total forest area under the Convention and the total forest area under the Kyoto Protocol are the same. All Luxembourg forest lands are considered managed within the meaning of the provisions of the Marrakesh Accords.

11.2 Land-related information

The land related information for the years 1989 and 2007 to support the KP reporting in Luxembourg was generated in the framework of the ESA funded "GMES Service Element Forest Monitoring in Luxembourg" carried out by LuxSpaceS.à.r.l. Data related to the year 1999 could be included due to an accompanying measure financed by the "Ministry of sustainable Development and Infrastructures" and implemented by LuxSpace. In 2012, new data was acquired and processed by the same company and in the same way as for the previous land use maps to ensure time series consistency.

11.2.1 Spatial assessment unit used for determining the area of the units of land under Article 3.3

The base data used for this reporting is the so-called OBS map data "Occupation Biophysiques du Sol" that is a detailed land use/land cover map in digital format covering the entire territory of Luxembourg. Three versions of the OBS map data set exist. The first OBS data set, the OBS89, was collected in the field for several years and published in 1989 by the Environment Ministry (now called the "Ministry of sustainable Development and Infrastructures"). The second data set for the OBS99 was collected based on aerial Colour Infra Red Ortho-photos and some field surveying for validation and completion. The third set, and currently the most recent, is the OBS07, which is an update of the OBS99 using Very High Resolution satellite images (1m pixel size) of the US commercial Earth observation satellite IKONOS.

The Minimum Mapping Unit (MMU) of the OBS89 is unknown. The Table 11–1 and Figure 11-2 provide information about the frequency distribution of polygon areas.

Table 11-2 -OBS89 data: Frequency of Polygons in size classes & cumulative percentages

Area (m^2) smaller than	Nr of Polygons	Cumulative %
100	73	0,15%
500	173	0,52%
1000	334	1,22%
1500	720	2,73%
2000	1063	4,96%
5000	8609	23,03%
10000	10005	44,02%
50000	18008	81,82%
100000	3846	89,89%
500000	3936	98,15%
1000000	575	99,35%
More	308	100,00%

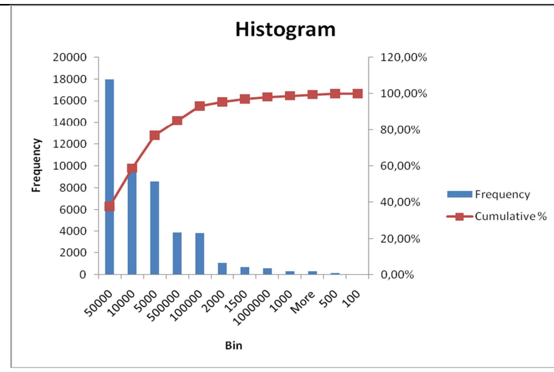


Figure 11-2 - Histogram of OBS89 data: Frequency of Polygons in size classes

The OBS99 MMU is in principle 2 500 m^2 (0.25 ha) but adapted for important but small areas, i.e. wetlands and little lakes/ponds to 1 500 m^2 (0.15 ha). Linear structures and parts of it are mapped as areas if their width is larger than 20m, other parts (<20m) are taken from the BD-L-TC and presented as lines. Figure 11-3 and Table 11–2 provide information about the frequency distribution of polygon areas.

Table 11-3 - OBS99 data: Frequency of Polygons in size classes & cumulative percentages

Area (m^2) smaller than	Nr of Polygons	Cumulative %
100	116	0,10%
500	3609	3,18%
1000	7220	9,35%
1500	7522	15,78%
2000	6693	21,50%
5000	27358	44,88%
10000	21546	63,29%
50000	32140	90,76%
100000	5867	95,77%
500000	4653	99,75%
1000000	243	99,96%
More	48	100,00%

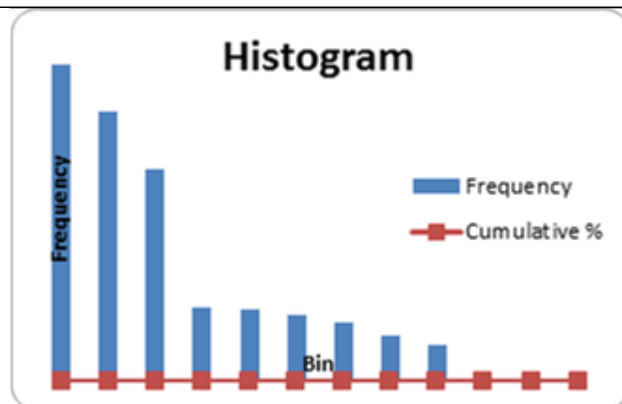


Figure 11-3 - Histogram of OBS99 data: Frequency of Polygons in size classes

The OBS07 MMUs correspond to those of the OBS99 with changes from OBS99 to OBS07 mapped with a MMU of 500 m^2. Table 11–3 and Figure 11-4 provide information about the frequency distribution of polygon areas.

Table 11-4 - OBS07 data: Frequency of Polygons in size classes & cumulative percentages

Area (m^2) smaller than	Nr of Polygons	Cumulative %
100	56	0,04%
500	36	0,07%
1000	9049	7,27%
1500	9377	14,72%
2000	8256	21,29%
5000	31000	45,93%
10000	23388	64,52%
50000	33643	91,27%
100000	5993	96,04%
500000	4693	99,77%
1000000	247	99,96%
More	47	100,00%

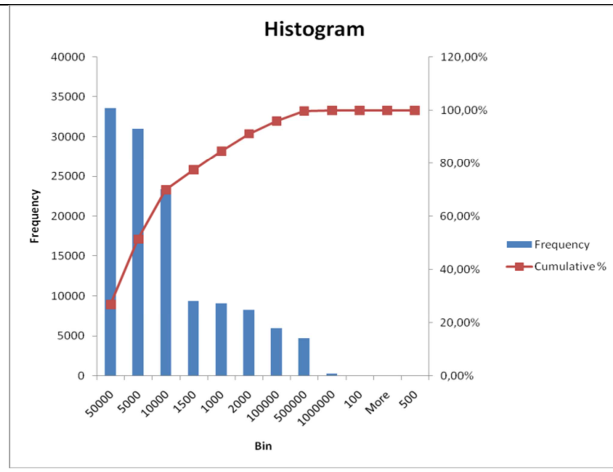


Figure 11-4 - Histogram of OBS07 data: Frequency of Polygons in size classes

11.2.2Methodology used to develop the land transition matrix

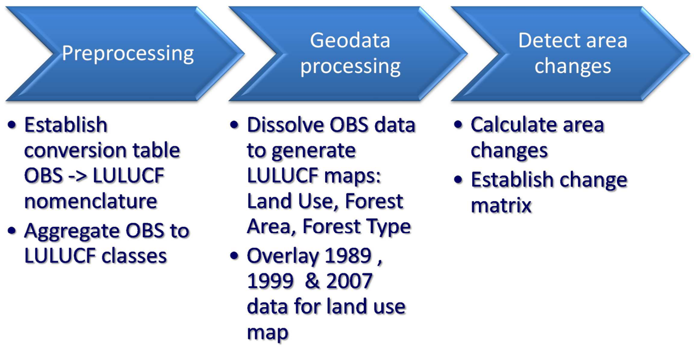
The generation of the LULUCF maps is based on the OBS and RE data. Data processing of OBS89, OBS99 and OBS07 follows the same processing scheme.

The original OBS categories for the years 1989, 1999 and 2007 were assigned to the relevant classes of the LULUCF nomenclatures. The correspondence of OBS89 respectively OBS99/07 classification to the LULUCF nomenclature has been established in close collaboration with the relevant administrations and experts. The conversion tables from OBS89-99-07 to LULUCF are presented in the section above. For RE data, the areas were directly assigned to the corresponding land use classes of the LULUCF nomenclature

After aggregation of the class assignments according to the LULUCF nomenclature (for OBS data), the next step in geo data processing (using Geographic Information System software “ArcGIS”) is to dissolve the polygons to the respective classes, i.e. all neighbouring polygons belonging to the same LULUCF class were aggregated to one single polygon. This process results in land use maps, i.e. LU89, LU99, LU07 and LU12.

In order to preserve the detail in the data for the generation of the area statistics, no generalisation was performed before the change detection. Change detection of Land Use / Forest types between the selected reference years 1989, 1999 and 2007 has been carried out by overlay (intersect) of the Land Use maps LU89, LU99 and the LU07 data sets. Figure 11-5 shows the processing steps.

Figure 11-5 – Processing chain for the creation of the land transition matrix (LULUCF maps)



For the change detection between the reference years 2007 and 2012, the overlay (intersect) of land use maps LU07 and LU12 has been carried out using the following processing steps. (Figure 11-6)

Figure 11-6 – Processing chain for the creation of LU12 and change detection between LU07 and LU12

The resulting maps of the intersection show the differences in land use and the changes from which land use class to which other one. The total area as computed from the GIS data sets differs slightly from the official area of the Luxembourg territory. This is simply due to resolution /scale and data processing inaccuracies in the data sets. Therefore, the areas derived from the geodata have been put in relation to the official area of Luxembourg (258 600 ha). It means that all areas resulting from the geodata processing are proportional to the official territory of Luxembourg that is 2 586km^2. From this data the change statistics are derived and illustrated in the change matrix.

An exception to the use of the LU maps has been made for LUC areas between cropland and grassland. When using LU figures, the LUC areas between cropland and grassland are too high because the areas with more than one land use change within 20 years are taken into account as LUC areas, whereas according to IPCC-GPG they should stay in their main category. In Luxemburg, and especially in the northern part of Luxemburg (Oesling), a crop rotation including temporary grass is largely used by the farmers. In this crop rotation, the changes temporary grass to annual crops are recorded as LUC grassland to cropland and the changes annual crops to temporary grass as LUC grassland to cropland when using OBS. An alternative way to estimate the LUC between cropland and grassland was found, using administrative data of the Ministry of Agriculture coming from the administration of the "aid scheme for the maintenance of the landscape and the natural environment and for encouraging an agriculture respecting the environment" an agro-environmental aid scheme administered by the Service d'Economie Rurale, an administration of the Ministry of Agriculture. As within this aid scheme a land use change from permanent grassland to cropland is not allowed, except in special circumstances and after a special authorization and as this aid scheme is largely taken up by the farmers, it was possible to estimate the annual LUC grassland to cropland (269 ha). As the part of permanent grassland in the utilised agricultural area is relatively stable, the annual LUC cropland to grassland is estimated to be of the same amount (269 ha). The LUC areas grassland to cropland respectively cropland to grassland going beyond 269 ha according to OBS are allocated to the category "cropland remaining cropland". For the years 2009-2015 detailed information on land use changes between cropland and grassland were extracted from the LPIS (see section 6.1.3.4).

11.2.3 Information on the size and geographical location of forest areas that have lost forest cover but which are not yet classified as deforested

With regards to clear cut areas (areas that lost forest cover but are not classified as "Deforested"), there are 2 distinct classes in the OB89 nomenclature:

- 32414 "végétation des coupes forestières",
- 32415 "recrus divers".

In addition to these polygons, so-called "new clear cut" areas were identified using Earth observation satellite data from the French SPOT1 satellite recorded in 1989.

With regard to clear cut areas (areas that lost forest cover but are not classified as "Deforested"), please refer to section 11.4.3 for more details

11.2.4 Method used to develop the land-transition matrix for GM an CM

Luxembourg has not elected CM and GM.

11.2.5 Maps and/or database to identify the geographical locations, and the system of identification codes for the geographical locations

The data sets used for the KP reporting is spatially explicit map data from the so-called OBS map "Occupation Biophysique du Sol" that is a detailed land use / land cover map in digital format covering the entire territory of Luxembourg.

Biophysical Land Cover Map 1989 at scale 1:10.000 - "Occupation Biophysique du Sol" OBS89

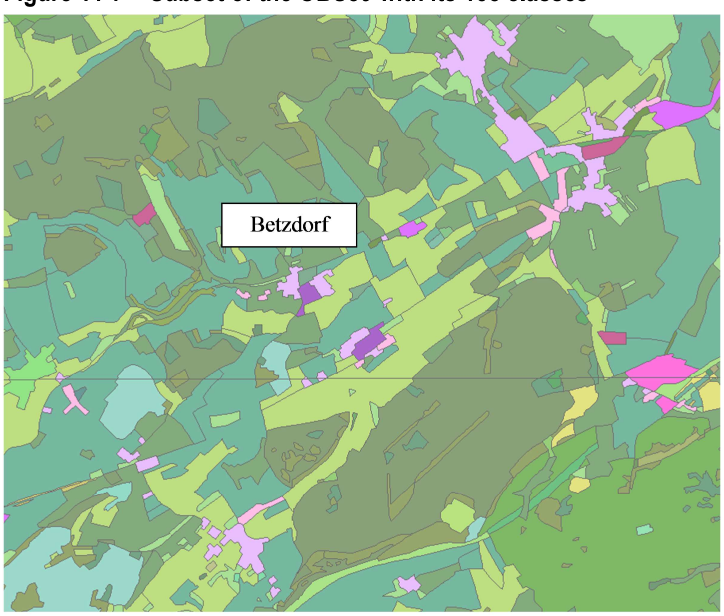
The first biophysical land cover map covering the entire Luxembourg territory consisted in a mapping and data collection in the field. Based on prepared aerial ortho photos showing delineated areas, experts from the "OekoFonds and the association "Hellëf fir d'Natur" mapped/classified the areas during field work according to a 6-level nomenclature with 5 main classes:

Table 11-5 – OBS89 Nomenclature at level1 and number of classes in levels 2-6

Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
Artificial areas	4	11	22	27	
Agricultural areas	3	4	9	10	3
Forest and semi-natural areas	3	9	27	37	
Wetlands	1	1	5	6	
Water surfaces	1	5	7	12	
Landscape elements	2	6	11		
Number of classes:	14	36	81	92	3

The OBS data has been provided by ANF as a shape file. The Minimum Mapping unit corresponds in principle to a scale 1:10.000, but in the data set there are about 250 polygons smaller than 500 m^2, 580 polygons smaller than 1000 m^2 of a total of 47650 polygons. There is no further detailed description or information on accuracy of the OBS89 available. In addition to this base, a SPOT satellite image mosaic of 1989 was used to identify new clear cut areas that are forest land without forest cover, which were not mapped in the OBS89 data but identified by photo-interpretation of the satellite imagery.

Figure 11-7 – Subset of the OBS89 with its 158 classes



The data has been used for LULUCF mapping for the year 1989.

Biophysical Land Cover Map 1999 – "Occupation Biophysique du Sol" OBS99

In 1999, the Ministry of sustainable Development and Infrastructure carried out an update of the OBS89 based on photo-interpretation of aerial Colour Infra-Red orthophotos covering the complete national territory in conjunction with the necessary field survey. The number of classes has been reduced to simplify the map and due to restrictions of the methodology (not all classes of OBS 89 could be photo interpreted). The aerial photographs were recorded in May (southern part of the country, optimal time for grassland and cropland before first cutting) and June 1999 (northern part, optimal time for forest areas during full developed vegetation period) at scale 1:15.000. The Minimum Mapping Unit is in principle 2500 m^2 (0.25 ha) but adapted for important but small areas, i.e. wetlands and little lakes/ponds to 1500 m^2 (0.15 ha). Linear structures and parts of it are mapped as areas if their width is larger than 20m, other parts (<20m), they are taken from the BD-L-TC and presented as lines.

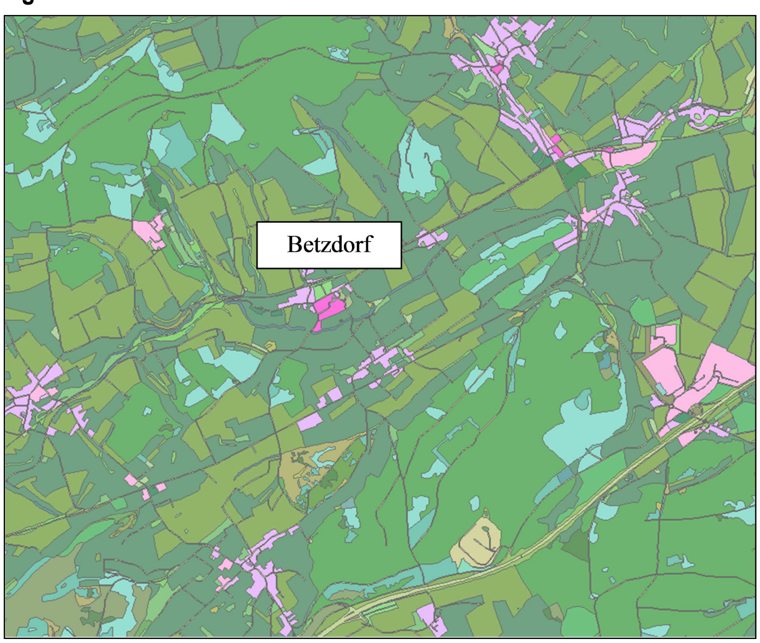
The map includes 4 landscape element categories (isolated tree, group of isolated trees, tree rows, hedges) and in total 77 land use/cover classes, divided in 5 broad categories:

Table 11-6 – OBS99 Nomenclature at level1 and number of classes in levels 2-5

Built-up and artificial areas (32 classes)	Agricultural areas (8 classes)
Forests and semi-natural areas (26 classes)	Wetlands (3 classes)
Water areas (18 classes)	

Concerning the nomenclature, the document describing the content of the OBS99 classes and showing examples of aerial photos has been made available by the Nature and Forestry Agency (ANF).

Figure 11-8 – Subset of the OBS99 with its 76 classes

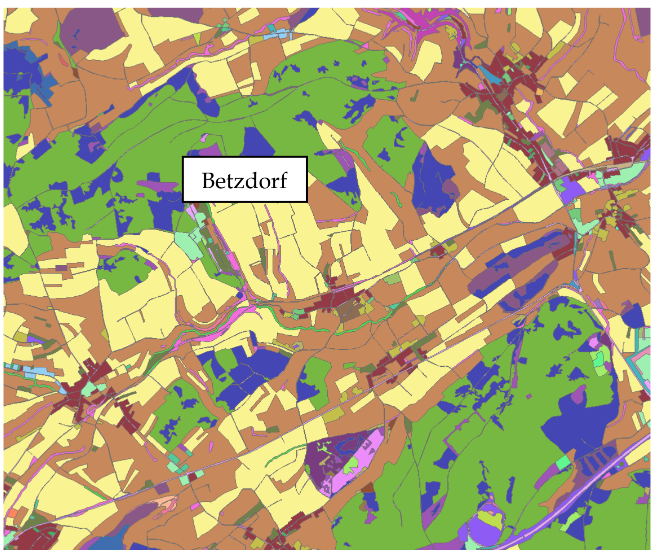


The data has been used for LULUCF mapping for the year 1999.

Biophysical Land Cover Map 2007 – "Occupation Biophysique du Sol" OBS07

In the framework of the ESA funded GSE-LUX-Land information service, this map has been generated by the service provider ESRI-BeLux. According to the accepted Integrated Approach for the "GSE extensions for Luxembourg", the detailed Biophysical Land Cover Map (OBS) of Luxembourg from 1999 was updated using the Very High Resolution IKONOS satellite image data acquired in July/August 2007. The Minimum Mapping Unit (MMU) corresponds to those of the OBS99 with changes from OBS99 to OBS07 mapped with a MMU of 500m². According to the GSE Land quality assurance and control procedures, the data has been validated by a third party, i.e. Geoville (Luxembourg), and accepted by the users, i.e. the Regional Planning Department of the Luxembourg Ministry of the Interior.

Figure 11-9 – Subset of OBS07 with its 76 classes



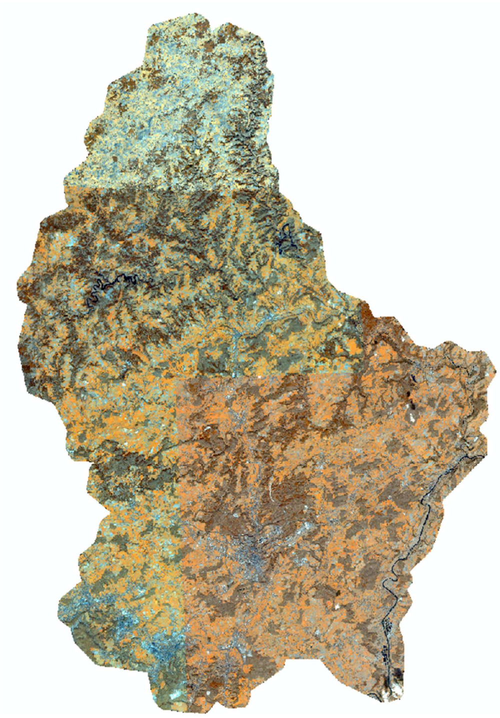
RapidEye Satellite land use map LU12

The RapidEye (RE) space segment is composed of five sun-synchronous Earth observation satellites providing large area, multi-spectral images with frequent revisits in high resolution (5m).

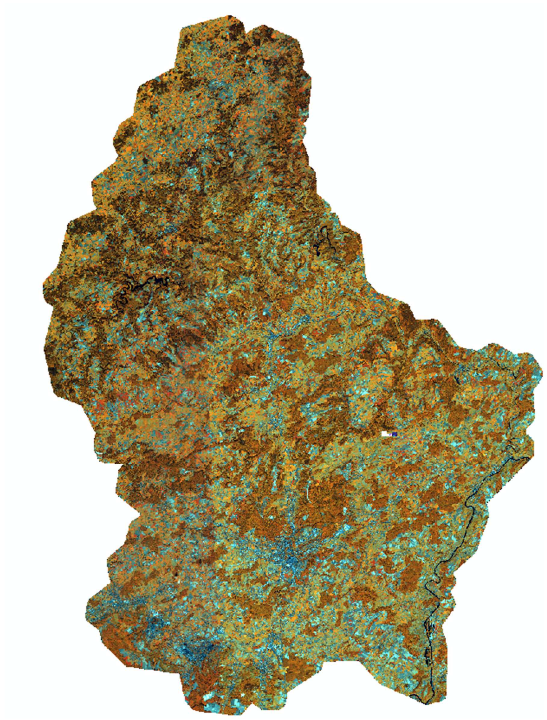
	RapidEye characteristics
Launch date	28/08/2008, constellation of 5 satellites
Orbit	Sun synchronous, 11:00h desc. Node, 96,7 minutes period, 630 km altitude
Sensor bands	Multispectral 5 bands, 6.5*6.5m² native sensor resolution, or resampled to **5m** pixelsize 1: Blue 440-510nm 2: Green 520-590nm 3: Red 630-690nm 4: Red Edge 690-730nm 5: Near IR 760-880nm
Swath-width	77km
Revisit Frequency	Daily

In preparation for this project, multi-temporal RapidEye images have been acquired in March, April and in August 2012 covering the entire Luxembourg territory. Multi-temporal imagery analysis means that the interpretation is based on at least 2 images over the Area of Interest (AOI) at different points in time, best in accordance with the vegetation period and the harvesting time. This allows a better distinction between cropland (i.e. arable land that is ploughed: bare in spring and after harvest) and grassland (permanent grass vegetation).

The acreage of the Area of Interest, i.e. the entire territory of the Grand Duchy of Luxembourg, is about 2586 km². As the change detection is based on the LU07 (OBS07) data layer, it is of utmost importance that the relevant data layers do exactly overlay ("fit") onto each other. The RE images were geo-rectified and projected onto the Luxembourg cartographic projection.



Mosaicked RapidEye images acquired in spring 2012



Mosaicked RapidEye images acquired in August 2012

11.3 Activity-specific information

11.3.1 Methods for carbon stock changes and GHG emission and removal estimates

11.3.1.1 Description of the methodologies and the underlying assumptions used

The methodologies and assumptions used for the reporting under the Kyoto Protocol Art. 3.3. and Art. 3.4 are equivalent to those used to calculate the UNFCCC categories 4.A.1 Forest Land remaining Forest Land, 4.A.2 Land converted to Forest Land and Forest Land converted to other land (4.B.2.1 & 4.C.2.1 & 4.D.2.2.1& 4.E.2.1 & 4.F.2.1). The methods to derive the activity data were described before in chapter 11.2.

Afforestation

Table 1-10 gives an overview of the parameters used for biomass and soil in AR areas.

Table 11-7 – C stock change factors in AR areas

Aforestation/Reforestation	Biomass			Soil	
	C before LUC (t C/ha*y)	Growth Age class: 0-20 years (t C/ha*y)	Growth Age class: 20-40 years (t C/ha*y)	C stock change after 20 years of LUC (tC/ha)	annual C stock change (t C/ha*yr)
Annual Cropland converted to Forestland	5.00	6.65	9.91	35.68	1.78
Perennial Cropland converted to Forestland	6.41	6.65	9.91	24.74	1.24
Grassland converted to Forestland	6.35	6.65	9.91	9.51	0.48
Wetlands converted to Forestland	0.00	6.65	9.91	111.09	5.55
Settlements converted to Forestland	4.34	6.65	9.91	67.85	3.39
Other land converted to Forestland	0.00	6.65	9.91	111.09	5.55

Table 11-8 Carbon-stock change as a result of afforestation

	Biomass growth (GgC)		DOM (GgC)		LUC from CM (GgC)		LUC from GM (GgC)		LUC from wetland (GgC)		LUC from settlements (GgC)		LUC from other (GgC)	
	above	below	litter	dead wood	Bio-mass	Soil	Bio-mass	Soil	Bio-mass	Soil	Bio-mass	Soil	Bio-mass	Soil
									OTHER under KP					
1990	1.82	0.37	0.67	0.16	-0.80	0.24	-2.10	0.16	0	0.10	-0.62	0.48	0	0.34
2013	26.30	5.27	5.70	1.67	-0.05	1.76	-0.26	1.46	0	0.70	-0.01	4.31	0	2.06
2014	27.34	5.47	5.08	1.49	-0.05	1.54	-0.26	1.32	0	0.60	-0.01	3.84	0	1.72
2015	28.38	5.67	4.45	1.30	-0.05	1.32	-0.26	1.19	0	0.50	-0.01	3.36	0	1.39

Deforestation

Table 1-11 gives similar information for D areas. In addition to losses of biomass in connection with conversion of forest land, losses in the areas of dead wood, litter and mineral soils are also considered. In the case of biomass, dead wood and litter, it is assumed that the pertinent losses take the form of emissions in the year of conversion. Emissions from mineral soils take place for a transition time of 20 years.

Table 11-9 – C stock change factors in D areas

Deforestation	Biomass: C before LUC (t C/ha*y)	Biomass: Growth (t C/ha*y)	Dead wood & litter: C before LUC (t C/ha*y)	Soil: C stock change after 20 years of LUC (tC/ha)	Soil: annual C stock change (t C/ha*yr)
Forestland converted to Annual Cropland	110.68	5.00	24.26	-35.68	-1.78
Forestland converted to Perennial Cropland	110.68	0.21	24.26	-24.74	-1.24
Forestland converted to Grassland	110.68	6.35	24.26	-9.51	-0.48
Forestland converted to Wetlands	110.68	0.00	24.26	-111.09	-5.55
Forestland converted to Settlements	110.68	1.29 / 0.15	24.26	-67.85	-3.39
Forestland converted to Other land	110.68	1.29	24.26	-111.09	-5.55

Note: Biomass growth values for Forestland converted to Settlements correspond to annual and perennial plants, respectively.

Table 11-10 Carbon-stock change as a result of deforestation

	Biomass loss (GgC)		Loss of DOM (GgC)		LUC to CM (GgC)		LUC to GM (GgC)		LUC to wetland (GgC)		LUC to settlements (GgC)		LUC to other (GgC)		N_2O (Gg N_2O)
	above	below	litter	dead wood	Bio-mass	Soil	Bio-mass	Soil	Bio-mass	Soil	Bio-mass	Soil	Bio-mass	Soil	
									OTHER under KP						
1990	-40.2	-8.7	-8.5	-2.1	0.30	-0.12	1.71	-0.13	0.00	-0.04	0.13	-0.30	0.00	-0.01	-0.001
2013	-4.2	-0.9	-0.8	-0.2	0.06	-1.04	0.12	-1.02	0.00	-0.46	0.24	-3.77	0.00	-0.06	-0.010
2014	-4.2	-0.9	-0.8	-0.2	0.06	-0.92	0.12	-0.90	0.00	-0.42	0.24	-3.52	0.00	-0.05	-0.009
2015	-4.2	-0.9	-0.8	-0.2	0.06	-0.81	0.12	-0.78	0.00	-0.37	0.25	-3.27	0.00	-0.05	-0.008

In the columns, showing the carbon stock changes for each type of land-use change, the gain in biomass is shown depending on the type of land the forest is being changed into. The losses of biomass due to forest removal are summed up under the category for biomass loss.

Forest management

The definition of forest management according to KP comprises all forest minus the forest areas which have been afforested or reforested since 1.1.1990 (Luxembourg has not elected carbon equivalent forests). The calculation for biomass gain and loss as well as carbon gain and loss in soils according to GPG differentiate between mature forests (older than 20 years) and forest that have been newly planted. Carbon stock changes of forests that have been planted between 1970 and 1990 have to be calculated separately within the forest management category. Those areas have been highlighted in grey in Table 1-14. Areas included in the AR category remain in the AR category and do not transit to the FM category. Not even after a period of 20 years.

For established forests it is assumed that the carbon content of litter does not change. It is assumed that litter levels (default value of 19,6 tC/ha) are reached after a transition period of 20 years. Dead wood levels are also assumed to be constant apart from the period between 2000 and 2010 where the national forest inventory highlighted an increase in dead wood following a change in harvesting practices.

In order to avoid double accounting the biomass loss due to deforestation has been subtracted from the harvest figures.

Table 11-11 Carbon-stock change as a result of forest management

	forestland						LUC to forestland prev.1990 (GgC) [172]				
	Biomass gains (GgC)		Biomass loss (GgC)		DOM (GgC)		Biomass gains (GgC)				
	above	below	above	below	litter	dead wood	above	below	soil	litter	dead wood
1990	239.61	50.85	-219.69	-47.19	0.00	0.00	34.58	6.97	25.09	12.77	3.13
2013	222.24	47.73	-124.55	-26.43	0.00	0.00					
2014	221.22	47.56	-140.90	-29.78	0.00	0.00					
2015	220.21	47.38	-151.94	-32.07	0.00	0.00					

Harvested wood products

According to 2013 Revised Guidelines: "It is good practice to apply the Tier 1 method as outlined in this section (i.e. reporting no net-emissions from HWP) only in the case that transparent and verifiable activity data for the default categories sawnwood, wood-based panels and paper and paperboard as outlined in section 2.8.1.1 are not available.

As described under the submission for UNFCC (chapter 1.8) the data on Harvested wood products are unreliable and hence the pool of harvested wood products is reported as instantaneous oxidation.

11.3.1.2 Justification when omitting any carbon pool or GHG emissions/removals from activities under Article 3.3

No carbon pool is omitted.

There is no practice of biomass burning at ARD areas in Luxembourg. Furthermore, forests are not fertilised in Luxembourg (expert judgement). So, fertilisation at AR areas do not occur. The new forestry code, that will be published this year, will most likely include a paragraph forbidding the application of fertilizer in forest (Code forestier – section 2.2.2.)

11.3.1.3 Information on whether or not indirect and natural GHG emissions and removals have been factored out

Due to a lack of available methods in the IPCC GPG and elsewhere, indirect and natural GHG emissions/removals have not been factored out.

11.3.1.4 Changes in data and methods since the previous submission (recalculations)

Since the previous submission the calculation of direct and indirect N_2O emissions associated with the loss of soil carbon stock due to land use changes (deforestation) have been refined.

[172] Carbon gain due to Land converted to forestland before 1990 and not reported under afforestation.

Also the current report contains a technical correction of the FMRL.

11.3.1.5 Uncertainty analysis

The details of the underlying calculations and associated errors on emission factors and activity data can be found in section 6.8.

Figure 11-10: uncertainty analysis for FM

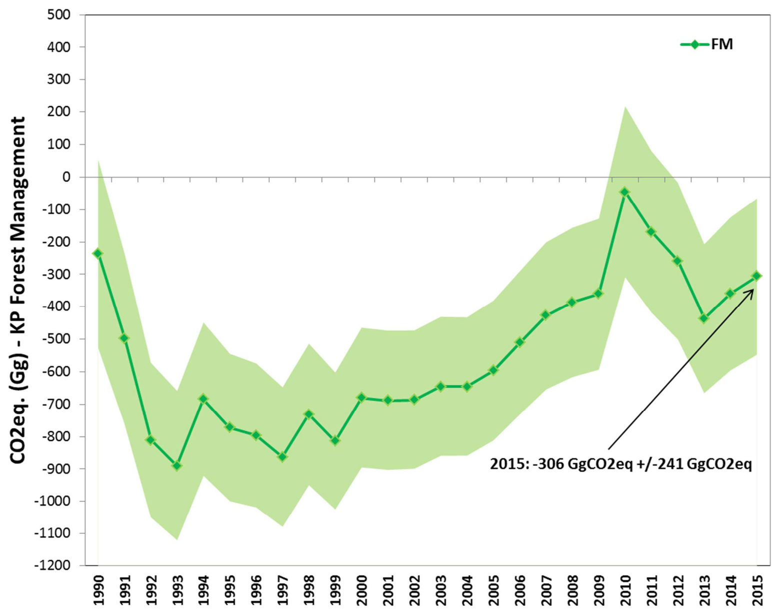


Figure 11-11: uncertainty analysis for D

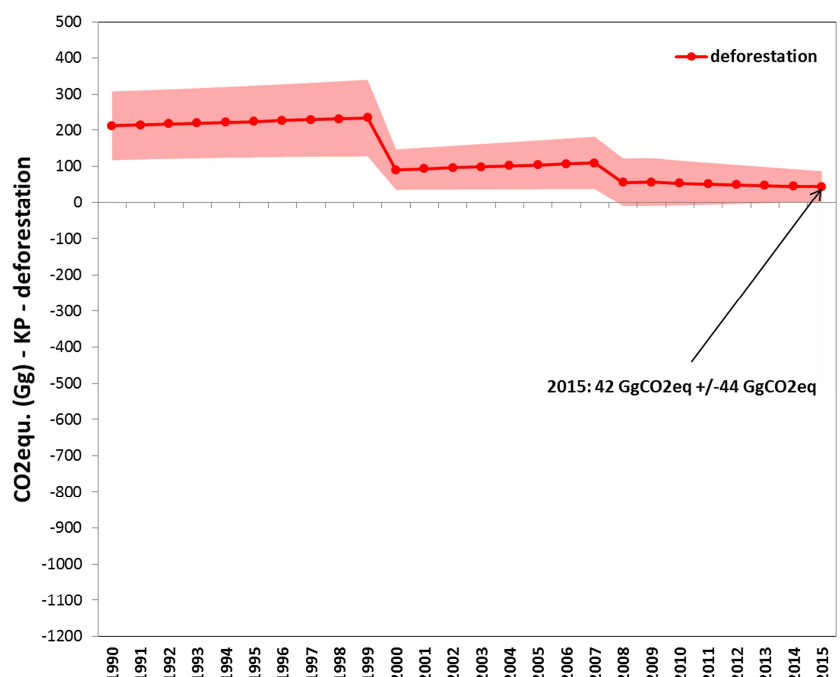
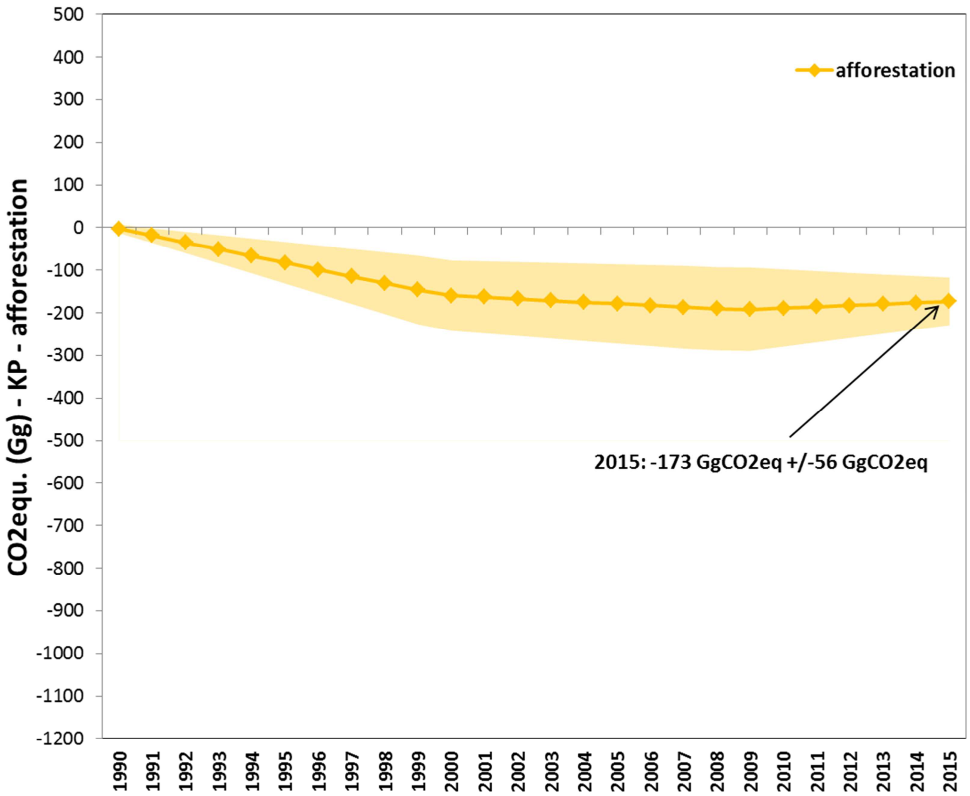


Figure 11-12: uncertainty analysis for AR



In the afforestation sector the absolute figures of uncertainty estimation are very low in the first years (starting in 1990). In this regard the afforestation sector is different from the two other sectors (FM, D). In the first years the afforestation sector is characterised with very low values of removals and the resulting carbon removals (and associated uncertainties) are hence very low. This is very different to the FM sector where overall balance of carbon emissions and removals can be close to zero with however a relative high uncertainty. In the latter case the high uncertainty can be attributed to the high uncertainty of the individual removals and emission.

11.3.1.6 Information on other methodological issues

The methods used to estimate emissions/removals from ARD activities are of the same tier method as those used for the UNFCCC reporting.

11.4 Article 3.3

11.4.1 Information that demonstrates that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2012 and are direct human-induced

The LU89, LU99, LU07 and LU12 land use maps are the main data providers for the greenhouse gas reporting of IPCC category forestland. The LU89, LU99, LU07 and LU12 maps represent the land use status in 1989, 1999, 2007 and 2012, respectively. Thus, the LU99 allows determining the differences in land use since the 1st of January 1990 and 1999, the LU07 between 1999 and 2007, and the LU12 between 2007 and 2012.

Luxembourg considers all LUC from and to forest land since 1990 as detected by the LU maps as "direct human induced" ARD lands. In addition, it might be noteworthy to mention that the total forestland area of Luxembourg is to be considered as "managed forest", so that the definition of forest management, as defined in the Marrakesh Accords, is applicable: "a system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of forest in a sustainable manner".

Information that demonstrates that activities under Article 3.3 are directly human-induced is derived from the National Nature Conservation Act (*Loi du 19 janvier 2004 concernant la protection de la nature et des ressources naturelles (telle qu'elle a été modifiée)*) downloadable in French). More specifically, chapter 4 of the act regulates the protection of fauna and flora, and in particular articles 13 and 17 state the following:

"*No change of use of forestland is permitted, except if the minister authorises it in the case of a general interest, or in view of an enhancement of agricultural structures. However, if such authorisation is given, compensating reforestation must be undertaken elsewhere (see note at the end of this section).*"[173]

The total AR areas since 1990 are approximately as large as the D areas since 1990 which is the result of the Nature Conservation Act that leads to direct human induced "compensating reforestations" (AR in sense of Kyoto-Protocol) under this Act when deforestations are allowed.

However, the LU maps (1) have an excellent fit with the time period under consideration for the Kyoto Protocol, (2) assessed the land use in the total area in Luxembourg and (3) detected rather balanced ARD areas in the observed time period which is in line with the legal situation in Luxembourg that requests "compensation reforestations" after deforestations. Therefore,

[173] Please note that the cited text is a translation/interpretation from French to English of some text passages of the legal text from art. 13 and art. 17. The relevant French legal text is cited in section 11.4.4)

Luxembourg considers all LUC from and to forest lands as observed by the LU maps as "direct human induced" ARD lands.

Luxembourg is also a densely populated, intensively managed country in which all areas nation-wide are subject to land-use plans. Preparation of, and compliance with, plans is monitored by the relevant competent authorities and of individual municipalities. Thus it may be assumed that all afforested areas fulfil the "directly human-induced" requirement, since the act of permission, as well as the act of mandating in a legally binding manner and the preparation and establishment of regional and landscape plans all presuppose active decisions by humans.

<u>Maintenance of agricultural land in good agricultural and environmental conditions</u>

The European Council Regulation (EC) no 1782/2003 establishing common rules for direct support schemes under the common agricultural policy and establishing certain support schemes for farmers and amending regulations, cf. articles 3 and 5 of this regulation:

"Article 3 – Main requirements

1. *A farmer receiving direct payments shall respect the statutory management requirements referred to in Annex III, according to the timetable fixed in that Annex, and the good agricultural and environmental condition established under Article 5.*
2. *The competent national authority shall provide the farmer with the list of statutory management requirements and good agricultural and environmental condition to be respected.*

"Article 5 – Good agricultural and environmental condition

1. *Member States shall ensure that all agricultural land, especially land which is no longer used for production purposes, is maintained in good agricultural and environmental condition. Member States shall define, at national or regional level, minimum requirements for good agricultural and environmental condition on the basis of the framework set up in Annex IV, taking into account the specific characteristics of the areas concerned, including soil and climatic condition, existing farming systems, land use, crop rotation, farming practices, and farm structures. This is without prejudice to the standards governing good agricultural practices as applied in context of Council Regulation (EC) No 1257/1999 and to agri-environment measures applied above the reference level of good agricultural practices."*

This European legislation was enforced by a national regulation with the *Règlement grand-ducal modifié du 25 novembre 2011 portant application, au Grand-Duché de Luxembourg, du régime de paiement unique, de la conditionnalité et du système intégré de gestion et de contrôle dans le cadre de la politique agricole commune.*, cf. article 18 paragraph 2 and Annex II of this regulation :

« *Art. 18. (1) Les dispositions à respecter dans le cadre de l'interdiction de réduction, de destruction ou de changement de biotopes prévue à l'article 17 de la loi modifiée du 19 janvier 2004 concernant la protection de la nature et des ressources naturelles sont fixées à l'annexe I.*

(2) Les exigences minimales pour les bonnes conditions agricoles et environnementales sont fixées à l'annexe II. »

Nevertheless, Luxembourg will continue to validate and, if needed, improve its reporting of ARD lands on the basis of all available statistics, data and administrative documents.

11.4.2 Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation

Art 13 of the National Nature Conservation Act states *that 3 years after a clear cut on forestland, the owner is pledged to reinstate the forestland* (see section 11.4.4 for the original French text). This means that areas of forestland, where a clear-cut has occurred, has to be considered as forestland, as no other use of forestland after a clear-cut is permitted. In addition, after a period of three years, the owner is forced to take measures to restore forestland, if it hasn't occurred already. So no deforestation can occur by law, except if permitted by a ministerial act. If this is the case, this is documented by the Ministry.

The OBS, which is the basis of the land use and land use change assessment in Luxembourg, takes these provisions into account and assesses clear-cut forest areas as forest land. Indeed, for the generation of the OBS, a specific photo-interpretation manual providing instructions for the OBS mapping (based on aerial orthophotographs and field surveys) including real world pictures was used. This manual was compiled by Hansaluftbild GmbH (Germany), the service provider who generated the OBS99 map (a pdf copy in German can be obtained upon request). In this mapping manual, two categories namely WSF (other forest areas (felled-area flora, wind throws), translated from German: "*sonstige Forstflächen (Schlagflur, Windbruch)*") and WAU (forest plantings (plantings, thickets, natural regenerations), translated from German: "*Forstliche Pflanzung (Aufforstung, Dickungen, Naturverjüngung)*") correspond to clear-cut areas. These areas are to be considered as forestland as they belong to the general category "forest". Opposed to these, are areas where no trees could be detected during the subsequent mapping exercise (in this case the LU07 mapping), and where another land use could be identified (for example sealed surfaces). These areas were then obviously not counted to forest land but to their new land use category (for "sealed areas" this would be "settlements"). In other words, if for a given area, which was classified in "forest land" in LU99, and in the following LU07 has been classified to another land use, then this area is assigned to "deforestation". If the same forest area, meaning an area with trees, was identified at a later stage as an area with no trees, and no other land use could be detected, then this area was identified as WAU respectively WSF and classified to "forest land".

11.4.3 Information on the size and geographical location of forest areas that have lost forest cover but which are not yet classified as deforested

With regards to clear cut areas (areas that lost forest cover but are not classified as "Deforested"), there are 2 distinct classes in the OBS89 nomenclature:

- « 32414 végétation des coupes forestière » and
- « 32415 recrus divers ».

In addition to these polygons, so-called "new clear cut" areas were identified using Earth observation satellite data from the French SPOT1 satellite recorded in 1989.

With regards to clear cut areas (areas that lost forest cover but are not classified as "Deforested"), there is one distinct class in the OBS99/07 nomenclature, i.e. "3134 Autres surfaces forestières (coupes rases, chablis)". The relevant areas were assigned to Forest Areas without trees, assuming crown coverage of <10% (code 331).

Table 11-12 – Areas having lost forest cover but not classified as deforested (1989, 1999, 2007, 2012)

OBS Class	LU class	Area in OBS89 (ha)	Area in OBS99 (ha)	Area in OBS07 (ha)	Area in LU12 (ha)
32414 Vegetation des coupes forestière	331 Forest Areas without trees	3912			
32415 Recrus divers	331 Forest Areas without trees	2699			
New Clear Cut areas (as identified from satellite images)	331 Forest Areas without trees	444			
3134 Autres surfaces forestières (coupes rases, chablis)	331 Forest Areas without trees		1441	1307	
	331 Forest Areas without trees				2380

11.4.4 Articles 13 and 17 of the National Nature Conservation Act

Loi du 19 janvier 2004 concernant la protection de la nature et des ressources naturelles (telle qu'elle a été modifiée):

« ***Art. 13.*** *Tout changement d'affectation de fonds forestiers est interdit, à moins que le Ministre ne l'autorise, dans l'intérêt général ou en vue de l'amélioration des structures agricoles.*

Le Ministre imposera des boisements compensatoires quantitativement et qualitativement au moins égaux aux forêts supprimées et cela sur le territoire de la commune ou de la commune limitrophe. Il peut substituer la création d'un autre biotope ou habitat approprié au sens de l'article 17 au boisement compensatoire.

Le Ministre peut déroger à l'alinéa qui précède dans l'intérêt de la conservation des habitats de l'annexe 1.

Après toute coupe rase le propriétaire ou le possesseur du fonds est tenu de prendre, dans un délai de 3 ans à compter du début des travaux d'abattage, les mesures nécessaires à la reconstitution de peuplements forestiers équivalant, du point de vue production et écologie, au peuplement exploité.]

Art. 17. *Il est interdit de réduire, de détruire ou de changer les biotopes tels que mares, marécages, marais, sources, pelouses sèches, landes, tourbières, couvertures végétales constituées par des roseaux ou des joncs, haies, broussailles ou bosquets.*

Sont également interdites la destruction ou la détérioration des habitats de l'annexe 1 et des habitats d'espèces des annexes 2 et 3.

Sont interdits pendant la période du 1er mars au 30 septembre:

a) la taille des haies vives et des broussailles à l'exception de la taille des haies servant à l'agrément des maisons d'habitation ou des parcs, ainsi que de celle rendue nécessaire par des travaux effectués dans les peuplements forestiers;

b) l'essartement à feu courant et l'incinération de la couverture végétale des prairies, friches ou bords de champs, de prés, de terrains forestiers, de chemins et de routes.

Le Ministre peut exceptionnellement déroger à ces interdictions pour des motifs d'intérêt général.

Le Ministre imposera des mesures compensatoires comprenant, si possible, des restitutions de biotopes et d'habitats quantitativement et qualitativement au moins équivalentes aux biotopes et habitats supprimés ou endommagés. »

11.4.5 Information on emissions and removals of greenhouse gases from lands harvested during the first commitment period following afforestation and reforestation on these units of land since 1990 consistent with the requirements under paragraph 4 of the annex to decision 16/CMP.1 (paragraph 8 (c) of the annex to 15/CMP.1)

The average age for these lands during the first commitment period is 10 years. No forest land in Luxembourg is clear-cut or even thinned by the age of 10 years. The first thinning is usually made after the age of 20 years depending on growth and the type of trees planted.

11.5 Article 3.4

11.5.1 Information that demonstrates that activities under Article 3.4 have occurred since 1 January 1990 and are human-induced

<u>Forest management</u>

Since an integrated procedure is used for surveying forest lands, land-use changes and the carbon-stock changes caused by relevant activities, the statements made in section 11.4.1 also apply for the activity "forest management".

Luxembourg is a small country and in general the pressure on land is very high. This means that the pressure on the use of wood out of forests is also very high. A more recent development has however seen the promotion of "forests without yield" (RFI- reserve forestière intégrale) in the sense that no harvest activity is taking place and the forests are left untouched in order to increase biological diversity. The total area of these forests is 1 250 ha (2014) which represents 1,1 % of the total forest area in Luxembourg. Those areas still fulfil the criteria for "forest management" as according to Decision 16/CMP.1, "Forest Management" is a *system of practices for stewardship and use of forestland aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner*.

11.5.2 Information relative to cropland management and grazing land management for the base year

Luxembourg has not elected CM and GM.

11.5.3 Forest management

The requirement that forests are to be managed sustainably, with a view to fulfilling ecological (including biological diversity), economic and social functions is anchored in the National Nature Conservation Act (*Loi du 19 janvier 2004 concernant la protection de la nature et des ressources naturelles (telle qu'elle a été modifiée))* downloadable in French). More specifically, chapter 4 of the act regulates the protection of fauna and flora.

In order to encourage a sustainable exploitation of forest, subsidies can be granted for certain types of forest management in private forests (Règlement grand-ducal du 13 mars 2009 concernant les aides aux mesures forestières en agriculture et en forêt downloadable in French)

The sustainable exploitation of public forests is safeguarded by the following legislative texts:

- Ordonnance du 13 août 1669 sur le fait des Eaux et Forêts (Extrait)
- Loi du 8 octobre 1920 concernant l'aménagement des bois administrés (telle qu'elle a été modifiée)
- Arrêté ministériel du 8 mai 1922 concernant le service d'aménagement des bois administrés (tel qu'il a été modifié)
- Instructions du 18 novembre 1952 concernant l'aménagement des forêts soumises au régime forestier

- Instructions du 11 mars 1987 modifiant et complétant celles du 18 novembre 1952 concernant l'aménagement des forêts soumises au régime forestier
- Circulaire ministérielle du 3 juin 1999 concernant les lignes directrices d'une sylviculture proche de la nature

A new forestry code is currently being developed which will update the current legislation and put an even stronger focus on sustainable forestry and protection of fauna and flora. This new code is expected to be published and put in legislation during the course of the year 2017.

11.5.3.1 Demonstration of methodological consistency between the FMRL and accounting for FM and technical corrections on the FMRL

Pursuant to resolution 2 / CMP.793, for the second commitment period of the Kyoto Protocol, anthropogenic greenhouse-gas emissions from sources and sinks that result from forest management under Article 3.4, are to be accounted against the Forest Management Reference Levels (FMRL). In each case, the FMRL contains a value that projects the average annual net emissions from forest management, in the second commitment period, from historic data and political decisions.

For Luxembourg, a FMRL of –0.418 $MtCO_{2eq}$ per year was calculated, during the submission of information on forest management reference levels, by the European Union. Luxembourg did not submit a calculation of a FMRL as can be seen on the UNFCCC website http://unfccc.int/bodies/awg-kp/items/5896.php and as a consequence the FMRL calculated for the submission under the EU has been taken for Luxembourg.

The IPCC KP Supplements require a technical correction of the FMRL if methodological changes result in calculation of the time series, if new historical data become available or if pools are included in current reporting that have not been taken into account in the FMRL. Those conditions are fulfilled as the current FMRL does not use the methodological approach employed in Luxembourg and hence a technical correction of the FMRL was carried out.

11.5.3.2 Technical correction of the FMRL

11.5.3.2.1 Projections for the category Forest Management

The carbon storage and emissions in forests are governed by the balance of the yearly biomass growth of trees on the one hand and removals of harvested wood on the other hand. The yearly biomass growth in forests is based on the age and type of forest trees and is hence predictable and well documented in the NFI. The harvest rate or wood removal is however less predictable as it is based on a range of factors such as:

- Forest age structure
- Species composition

- Harvest policy
- Location of forest (accessibility of the forest – hillside location)
- Amount of natural unmanaged forest
- Wood price and demand
- Natural disturbances
- Financial incentives

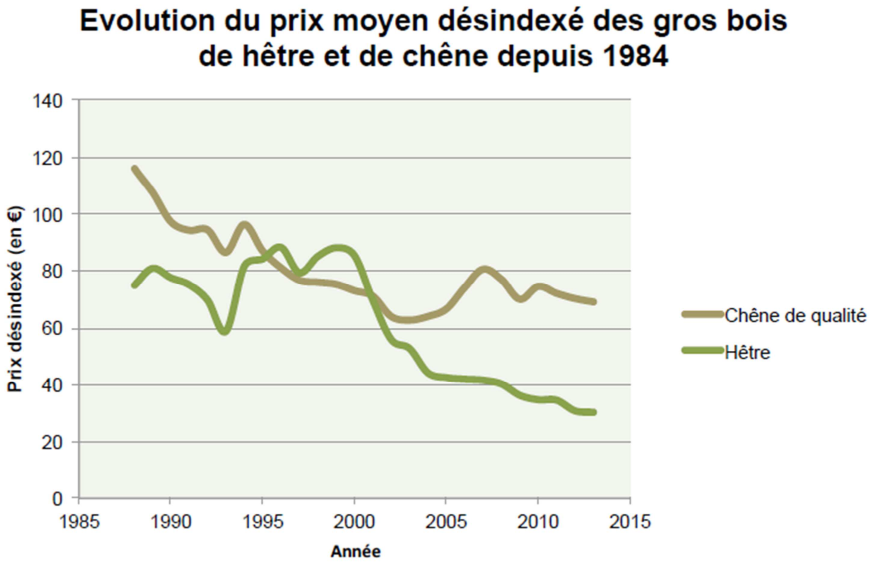
Age structure, species composition and past management practices are all known factors that change slowly and can be used for simple predictions of wood harvest. Future wood demand and management are driven by policies and market demand which are unknown and may change rapidly. Those latter factors increase the uncertainty of the prediction models.

In order to make projections a number of hypotheses have to be made with regards to those individual parameters.

The forest age structure is a good indicator for the amount of wood reserves available for harvest as it forecasts when the wood is ready to harvest. This is often referred to as unavoidable harvest and is the main rationale behind using a Forest Management Reference Level. As will be highlighted in this report, the mere availability of wood, that is ready to be harvested, does however not necessarily mean that the harvest will take place. Trees can remain in the forest for a much longer time after their optimal harvest age and can thus act as available wood reserve for years to come. With regards to forests under private ownership, harvest rates of mature forest are mainly driven by wood price and legislation. Harvest rates in forests under public ownership are also driven by wood prices but are mainly driven by harvest policy, which increasingly take into account environmental concerns.

11.5.3.2.2 Wood Price

Figure 11-13: price evolution for beech (green) and oak (brown) wood (in Belgium) (Fédération Nationale des experts forestiers, 2016)



The price evolution of wood price in Belgium can be seen in

. As the wood market in Luxembourg is highly entangled with the Belgium market, prices in Belgium are a good indication for prices in Luxembourg. The figure here above shows the price evolution of oak and beech in real terms (without indexation). Both price categories have seen a sharp decline over the last two decades and are still below their levels of 1990. The financial crisis seems to have exasperated this trend. Considering that prices have been low for a long time it is possible to imagine that a lot of forest owners have been deferring harvest in the hope that prices would recover. A slight recovery in wood prices might prompt those land owners to increase harvest.

11.5.3.2.3 Wood demand for energy use (heating purposes)

Due to the renewable energy policy pursued by Luxembourg wood demand for energy use is likely to increase over the next years.

With regards to new residential buildings the legislation favours the use renewable energies by taking into account the type of heating source in the calculation of the energy performance certificate. Furthermore the subsidies on pellets wood boilers are very interesting and are available for existing buildings as well as new buildings.

Figure 11-14: cumulated number of small scale residential central wood burners (based on subsidy application)

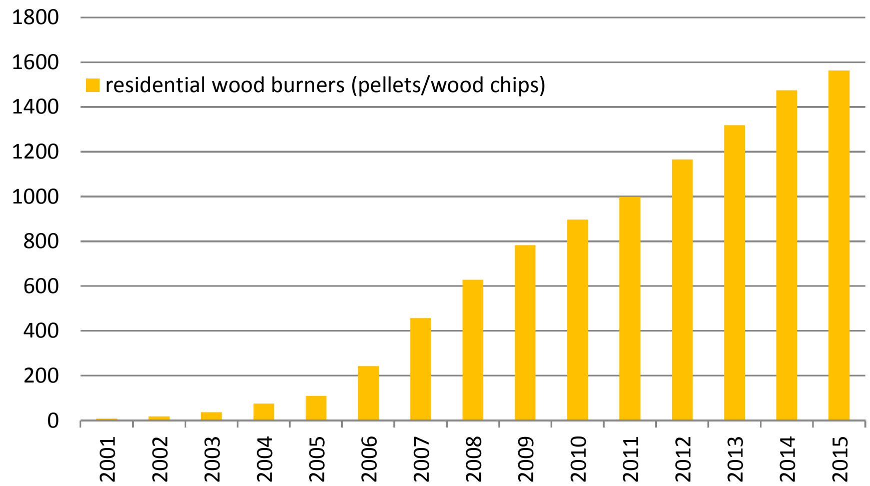


Figure 11-14 gives an overview of the evolution of the number of subsidies payed for central wood (pellets of wood chips) burners used in residential buildings. This statistic does not include wood stoves but only central burners which act as sole heating system. The figure shows a steady increase of those heating systems in the last years. The total number of 1 242 represents however only a fraction of the total building stock in Luxembourg. It is also important to highlight that, unlike PV-panels, building owners will only consider purchasing heating systems, based on pellets, when their existing heating system becomes redundant. With a typical life expectancy of 20-30 years for heating systems, subsidies for renewable energies will only be taken on gradually and hence the upward trend seen in this chart is likely to increase.

Figure 11-15: cumulated number of large scale (>50 kW) communal wood burners and corresponding wood consumption

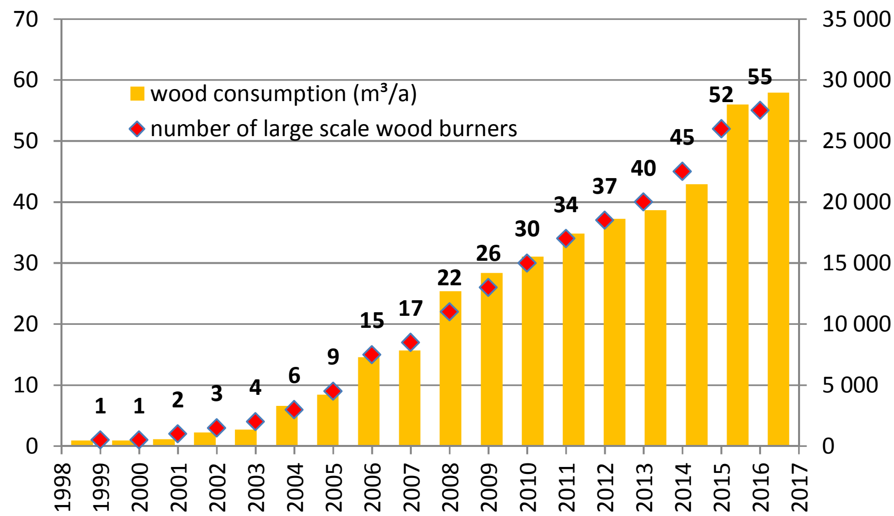


Figure 11-15 shows the evolution of the number and the consumption of large scale wood chips burners (large scale privately owned pellets burners are not included) operating in Luxembourg. Between 2010 and 2015 the installed power of those heating systems has tripled and hence the quantity of wood consumed for energy purposes has increased from an initial value of less than 5 000 m^3 in 2005 to almost 30 000 m^3 in 2014. The wood consumption does not include the consumption of recently installed burners as no data is yet available and hence the real consumption is most likely higher. The use of locally sourced renewable energies (on the territory of the individual communes) is a very attractive option for communes which like to improve their environmental credentials. This is particularly important as a lot of forests are under communal ownership. Nevertheless the total number of wood burners installed is high (55) compared to the total number of communes (105) and a certain slowdown in the number of such systems installed can be expected.

A study on potential use of renewable energy, (Biermayr, et al., 2007), conducted in 2007 and revised in 2015 (Schön & Reitze, 2015) predicts the quantity of wood used for energy purposes could potentially increase to 185 000 m^3 by 2020. This figure also includes wood used for heating purposes in small wood stoves (+/- 15%) which does however seem slightly inflated.

Overall the analysis of these figures show that the demand of wood for energy purposes is expected to remain high and even increase over the years to come.

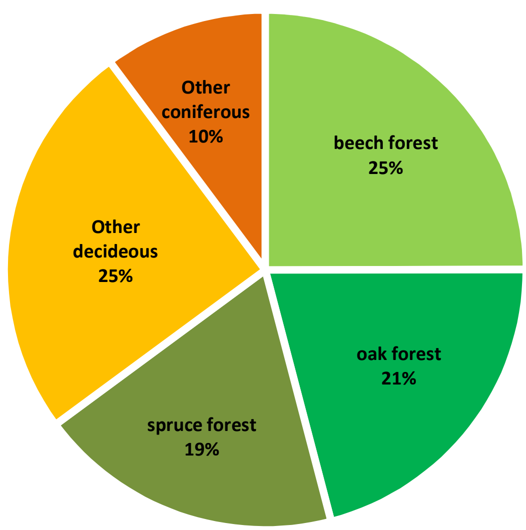
11.5.3.2.4 Projected harvest rate

In Luxembourg all forest, under public ownership, have to submit, once every 10 year, a report providing a detailed forest description (species composition, age structure, forest management) as well as the projected harvest rates for the next 10 years. Data projections for harvest rates in the public forests are hence available for approximatively the next 5 years. The calculation method, used to estimate the harvest rate, is prescribed and will, for this reason, be used for the purpose of calculating a FMRL. Forests under private ownership are not required to submit those forest management plans. In deciduous forests, harvest rates in private forests (3.3 $m^3/ha/a$) are lower compared to public forests (4,8 $m^3/ha/a$) but are essentially the same in coniferous forests (8,7 $m^3/ha/a$). The reasons for the reduced harvest rate in private deciduous forest are not known but can most likely be attributed to the depressed wood prices. The calculation method will nevertheless be applied to the total forest in Luxembourg and a correction factor (= 3.3/4.8) will be applied to the proportion of private deciduous forests.

In the following analysis the method proscribed by the ANF to establish these reports will be used to estimate harvest rates. It is hence assumed that management practices are not likely to change during the next decade. The method used and recommended by the forest agency is based on (Dubourdieu, 1997).

11.5.3.2.4.1 Species composition of forests in Luxembourg

Figure 11-16: forest tree species composition



Individual tree species have different rotation periods, different forest management practices and different maturity ages. Figure 11-16 represents the forest composition according to the different species. Beech (Fagus sylvatica L.) is the most important broadleaf tree species in Luxembourg and represents 25 % of the different forest types and is also commonly found in deciduous mixed forest (category other deciduous). Oak forests are also strongly represented but a distinction has to be made between oak forests and coppice oak forests (which lower harvest rates) that can be found in the North of the country. With regards to coniferous forests in Luxembourg Norway spruce (picea abies) is the most commonly found tree.

11.5.3.2.4.2 Calculation method

Harvest rates are typically determined by the age and the diameter of individual trees. The maturity age is the age of optimal harvest and depends on the type of trees and the intended use of wood. Trees planted for the purpose of energy use have a lower maturity age than trees planted for the use of construction timber. Apart from the coppice oak forests in the north of Luxembourg the majority of forest in Luxembourg have been planted in order to produce high quality wood and have thus quite high maturity ages. Wood can however be extracted from forest throughout their lifetime as regularly thinning is necessary in order to produce high quality wood. The wood harvested during thinning exercised is not only used for heating purposes but also in the wood industry (paper, heating, oriented strand board (OSB),…).

Once a forest has reached its maturity age the total wood stock could be harvested at once (clearfelling) and a new forest could be planted. In terms of forest management there is a clear shift away from clear-cut system to the selective felling of timber. Also, current legislation does not allow clearfelling in deciduous forests and only allows clearfelling in coniferous forest that are older than 50 years. In public forests deciduous forests that have reached their maturity age are generally fell over a period of 30 years and coniferous forest over a period of 10 years.

In order to sustainably exploit forest it is preferable to have an evenly distributed tree age structure. This will lead to a constant year on year harvest rate and will make the forest less vulnerable to natural disasters like windfall. In order to achieve an evenly distributed age structure the yearly forest area to be exploited is generally limited to the total forest area divided by the maturity age. This practice will lead to some parts of the forest to exceed the maturity age. There is a concern that ageing forest might be more prone to diseases and that productivity lessens. On the other hand, forest that have passed their optimum harvest rate, often still have a very high ecological value in terms of the divers fauna and flora that inhabits old and dying tree stems. The current forest management practice being practiced in Luxembourg accepts the perceived drawbacks of ageing forests and favours a sustainable management of the forests.

In order to estimate the harvest rate the method described by (Dubourdieu, 1997) and applied for the establishment of public forest management plans is used. First the maximum surface area to harvest in order to balance out the age structure is determined by the following formula:

$$S_e = {}^{s}/_{A}$$

where :

S_e = surface to balance ("surface d'équilibre")

s = total forest surface area of a given tree species

A = maturity age

The first formula determines the harvest rates for forests that have reached their maturity age and are completely harvested over a period of 10 years (in general coniferous forests). These forests area are referred to as strict regeneration.

$$P_{strict} = {V_{strict}}/_{d} + Z * b$$

where :

P_{strict} = annual harvest potential ("possibilité annuelle pour régénération stricte")

V_{strict} = total wood stock volume

d = considered period (10 years)

Z = coefficient depending on whether the regeneration effort is fast or slow. Z equals 0,5 when the regeneration effort is fast which is generally the case in the strict regeneration group

b = growth rate in regeneration group

Deciduous forest, having reached their maturity age, are generally harvested over a period of 30 years and are then referred to as extended regeneration group. The harvest potential over a 10 year period for an extended regeneration group is calculated as follows:

$$P_{élargi} = {V_s}/_{d} + Z * s * bo + K * {V'}/_{d} + (S - s) * b'o$$

where :

$P_{élargi}$ = annual harvest potential on regeneration group

d = considered period (10 years)

S = total surface area of considered group

s = surface to be regenerated over the considered period of time (considering that the total surface is supposed to be regenerated over a period of 30 years s = S/3)

V = total wood stock on surface S

V_s = total wood stock volume on surface s (V_s=V/3)

V' = surplus on wood stock on the remaining surface area S-s

bo and b'o = annual growth rate on surface area s and S-s

Z = coefficient depending on whether the regeneration effort is fast or slow. Z equals 0,5 when the regeneration effort is fast which is generally the case in the strict regeneration group

K = 0,2 in order to consider that 20% of wood is harvested in order to prepare for regeneration

The remaining forests that have not reached their maturity age are thinned on a regular base (typically after the age of 40 years for deciduous forests and 20 years of coniferous forests) and hence a harvest rate can be calculated. Those forests are referred to as an improvement group ("quartier d'amélioration") and the harvest rate are dependent on the age structure and species and have been extracted from harvest tables.

Table 11-13: rotation age by tree species

	Rotation age (years)
Beech (Fagus sylvatica) L.)	160
Oak	200

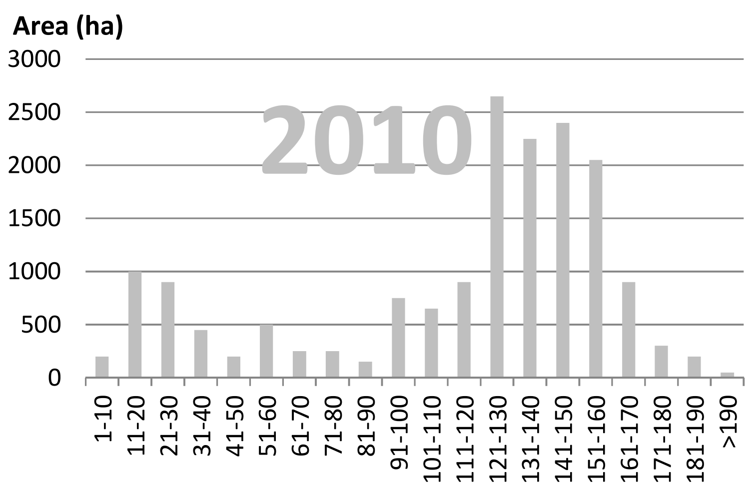
Norway spruce (Picea abies (L.)	70
Other deciduous	80
Other coniferous	80

The maturity ages are prescribed for public forests (Code de l'environnement 2011 – Vol 3 - Instructions du 18 novembre 1952 concernant l'aménagement des forêts soumises au régime forestier.). Oak: 140-200 years, beech: 140-160 years, other deciduous: 80 years, pine: 80-120 years, spruce: 70-100 years and fir: 100-140 years.

11.5.3.2.4.3 Beech forests

Beech (Fagus sylvatica L.) is the most important broadleaf tree species in Luxembourg and is a major contributor to present and future harvest rates.

Figure 11-17: age structure for beech forests



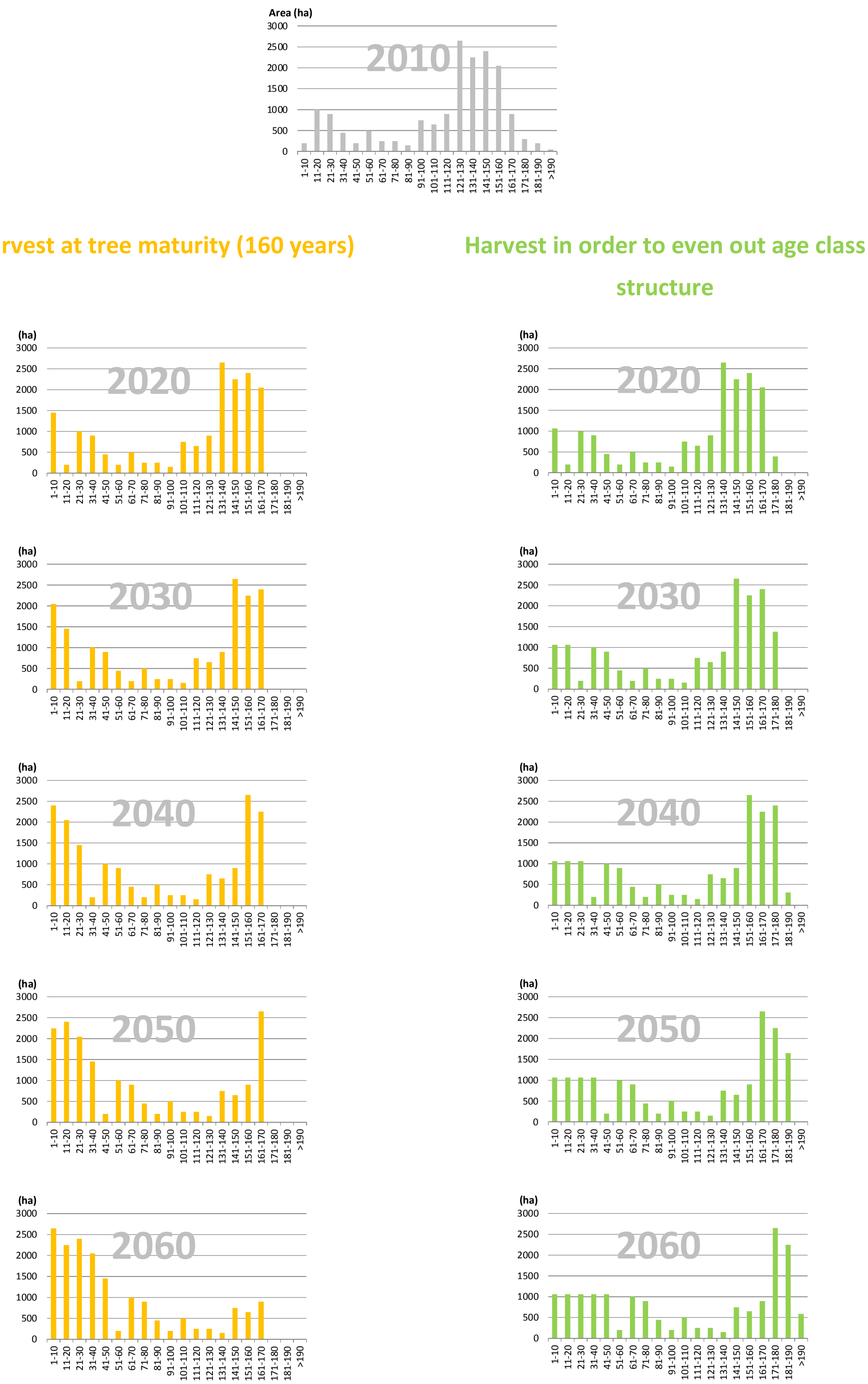
Analysing the age structure in Figure 11-17 of beech forests in Luxembourg it becomes apparent that the proportion of mature forests (120–180 years) is very high and the proportion of middle aged forests (41–80 years) is very low. Considering the uneven age structure in beech forest it would be necessary to limit harvest rates in order to guarantee a healthy harvest in the future.

One problem with ageing beech trees is that older trees, of larger dimensions, are capable of forming coloured heartwood, which is usually developed as red heart. The occurrence of larger red hearts reduces the value of beechwood considerably as red heartwood is poorly suitable to serial production due to instability in colour and appearance structure. This means that there is a strong incentive to harvest beech wood at its maturity rate. Figure 11-18 compares the evolution of the age structure for the two possible harvest scenarios:

- Harvest rate a tree maturity where beech trees are harvested as soon as the age of 160 years is reached
- Harvest rate limited to S_e in order to balance out age structure

Projections have been extended to 2080 in order to highlight the evolution of age structure.

Figure 11-18: possible harvest management scenarios for beech forests



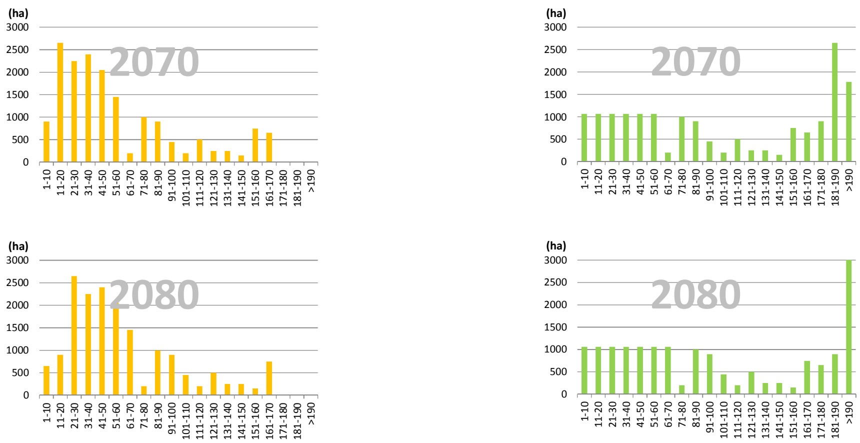
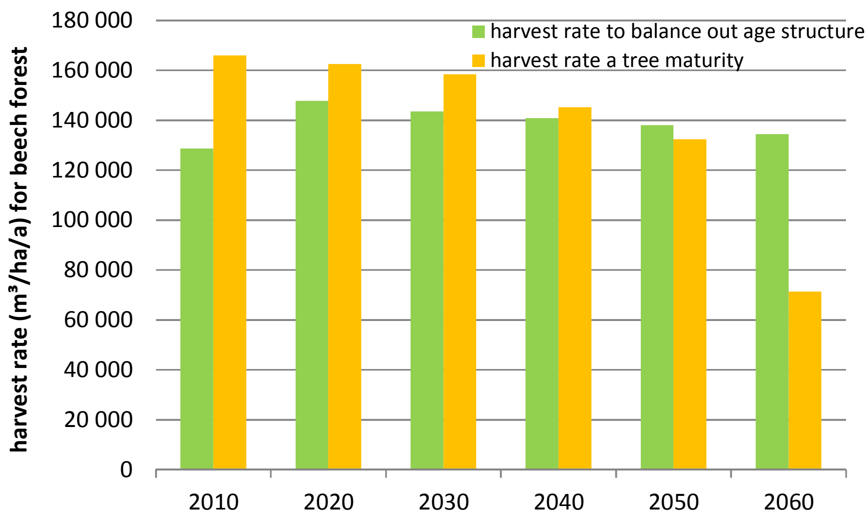


Figure 11-19: potential harvest rate for beech forests



The two scenarios illustrate well the difference between a maximum short term harvest at tree maturity and a sustainable harvest aimed at balancing out forest age structure. The difference is most noticeable during the period of 2010-2020 as well as in the period after 2050 where a significant drop in harvest rate would be noticed for the scenario at tree maturity. On average, between 2010 and 2040, the difference between the two scenarios amounts to 18 000 m^3/ha/a. The difference is however not as pronounced as Figure 11-18 would lead to imagine because both scenarios have a base harvest for thinning purpose which can amount to over 50 % of total wood harvest.

11.5.3.2.4.4 Oak forests

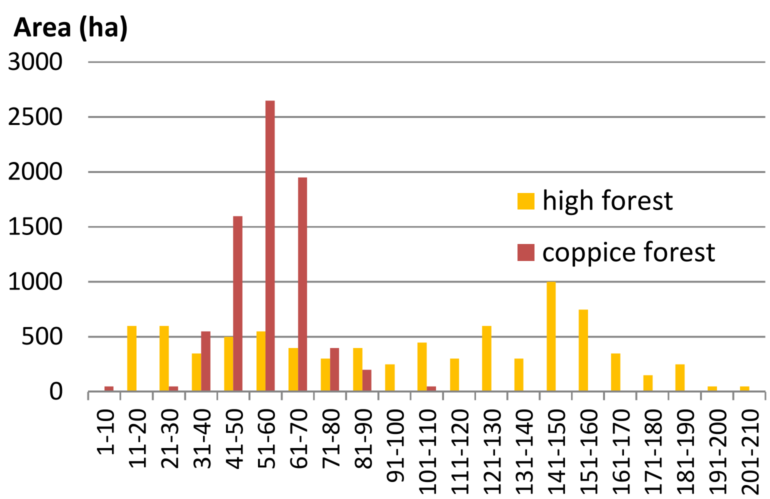
In Luxembourg there are two types of oak forest. On the one hand there are common high oak forest for timber production but on the other hand there are also coppice oak forests ("Lohhecken").

In Europe, oak used to be a common source of tanbark, used by tanneries in order to produce leather. The bark is taken from young branches and twigs in oak coppices and the remaining wood used generally as fire wood. According to (Hermes, 2006) production of oak bark used to be around 7 810 Tons in 1947 and has continuously fallen since the introduction of more efficient chemical tanning products. Wood production in these forests is not very high as the high production of bark removes a lot of nutriments from the forest soil.

Figure 11-20: illustration of coppice oak forests (Lohhecken) in Luxembourg (Hermes, 2006)

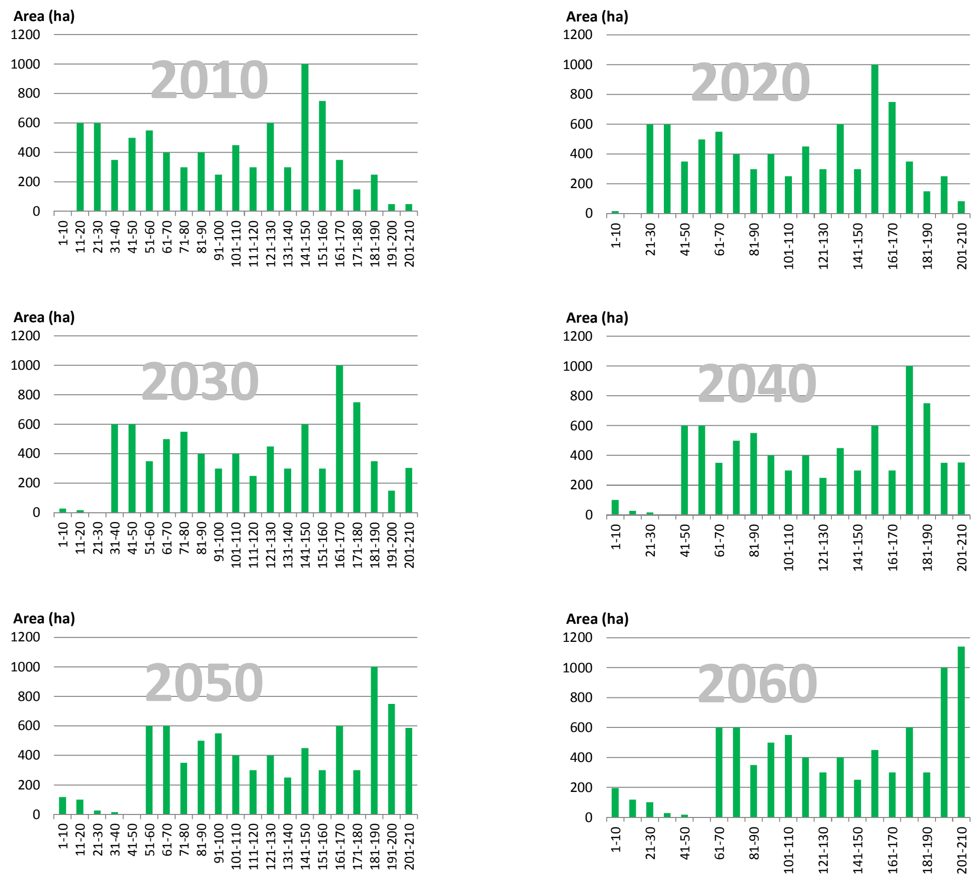
Wood growth in coppice oak forest can be estimated at around 4,1 – 4,6 m³/ha/a, but according to the results of the NFI harvest rates is estimated at about 1 m³/ha/a which highlights the fact that these forest are very underutilised. This harvest rate will be used for further calculations and will be set to a constant value for the years leading up to 2050. It would however be imaginable that some of these forests will be completely harvested. This could lead to a harvest of 75-115 m³/ha, which spread over the period of 30 years could potentially increase the harvest rate by up to 25 000 m³/a. It is however more likely that these forests will gradually evolve in high forests. Considering their young age (see ***Figure 11-21***) it will likely take a few more decades before higher harvest rates can be expected in those forests.

Figure 11-21: age structure for coppice oak forest and oak high forest in Luxembourg



The age structure of the oak high forest in Luxembourg shows, in comparison to beech forest, a relative balanced age structure between 0 and 160 years. The maturity age of oak forests is however 200 years which means that in the next 40 years the harvest rates in oak forests will be very low.

Figure 11-22: evolution of age structure of high stand oak forests

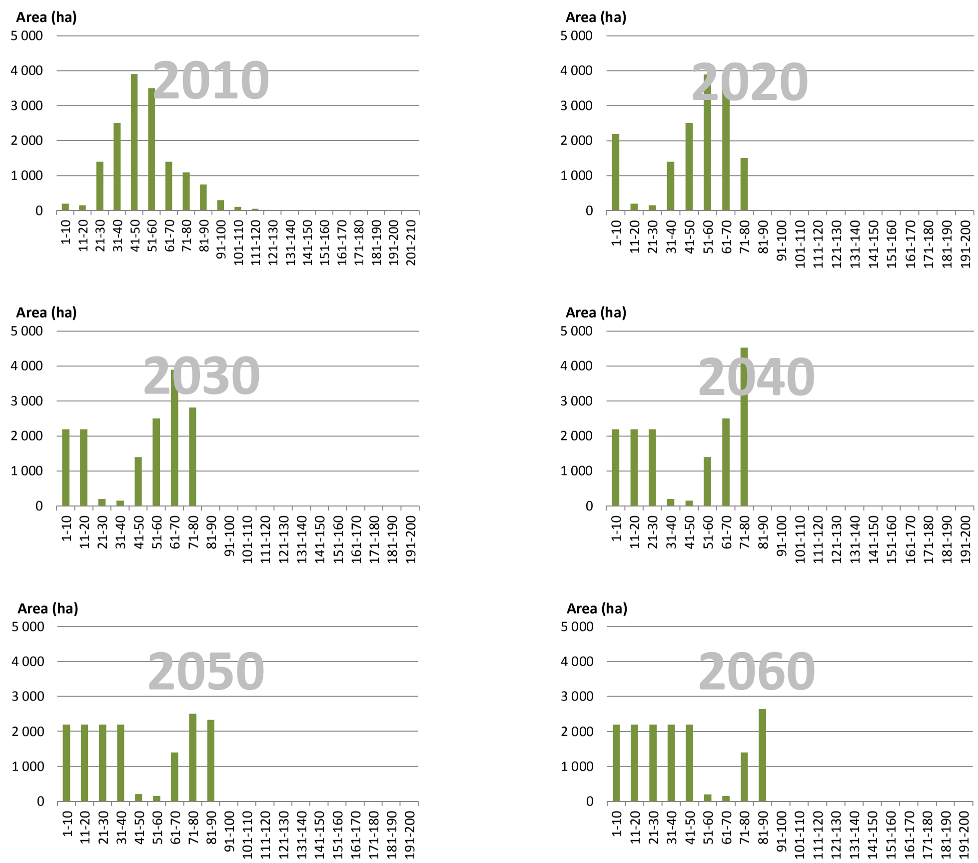


11.5.3.2.4.5 Spruce forests

The strong increase in wood harvest from 2010 onwards is partly due to higher harvest rates in private coniferous forests which have reached the legal threshold of 50 years (in Luxembourg clear cutting in coniferous forests is not allowed before the age of 50 years).

The evolution of age structure in spruce forests shows a medium wood production for the next decades to come.

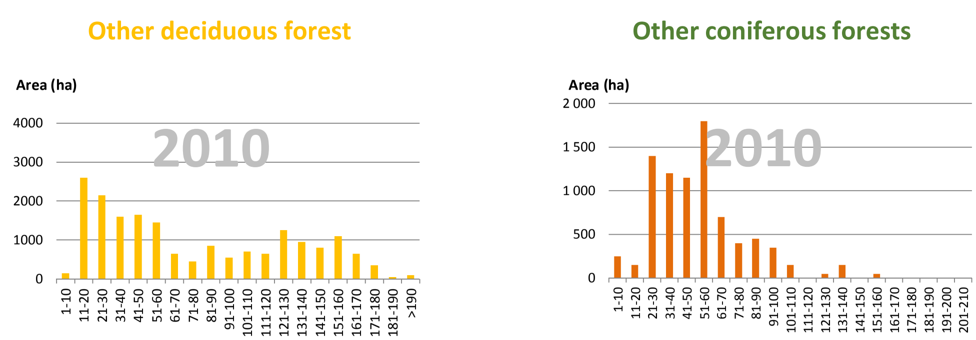
Figure 11-23: evolution of age structure of high stand oak forests

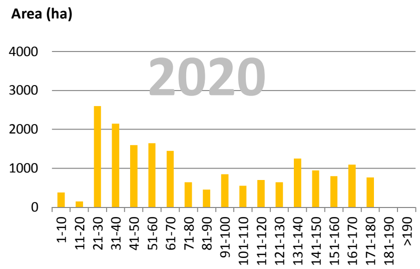


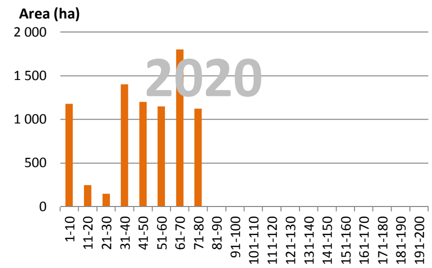
11.5.3.2.4.6 Other forests

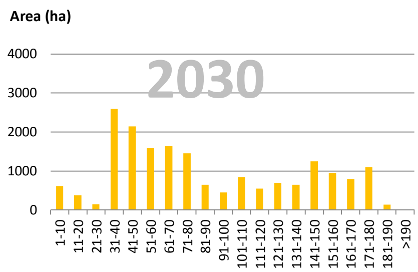
The category other forests is split between deciduous and coniferous forest which have both different age class structures and hence different harvest potentials

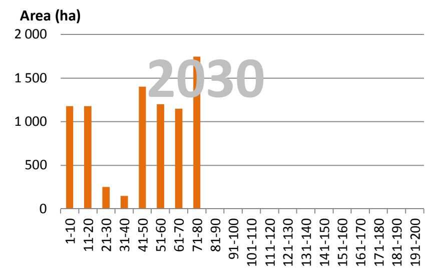
Figure 11-24: evolution of age structure of other deciduous and coniferous forests

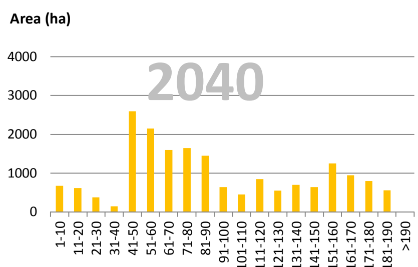


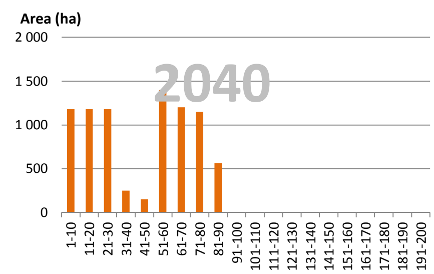


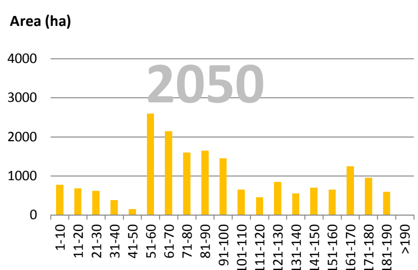


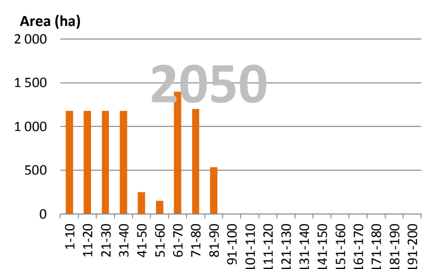












11.5.3.2.4.7 Projected harvest rate

According to (Genot & Kalmes, 2014) 1 250 ha of forests are declared as nature reserve (RFI-réserve forestière intégrale) and can hence not be exploited. In the medium to long term the forest agency is aiming to increase this to 5% of the total forest area (4 500 ha).

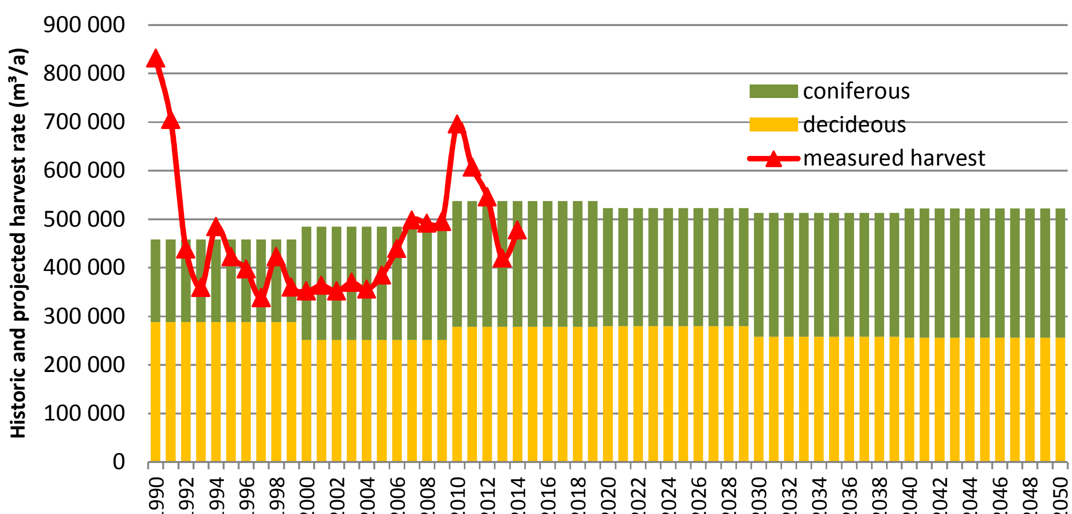
According to the same study a further 4 640 ha are situated on a slope > 60 % and can hence only be exploited with great difficulty. The conservative approach is taken that those forest areas are considered unmanaged and the assumption is taken that carbon emission and removals are in balance. This is not entirely correct as it is likely that over the years an accumulation of dead wood and increase in soil carbon content can be observed on those areas. Nevertheless dead wood and soil carbon content are measured during NFI. A higher average dead wood content on the remaining forests and is thus accounted for under the measurements from the NFI.

Table 11-14: area of forestland used for projection between 2013-2020

	Surface area (kha) average 2013-2020
Forest management	
managed	78,26
RFI	9,14
Afforestation (since 1990)	8,68
Deforestation (since 1990)	5,77

The calculated harvest rate is multiplied with the ratio of forest management area + afforestation area – RFI area to forest areas used to determine the harvest rate. The ratio also includes the ratio of coniferous trees to deciduous trees that originates from the NFI. Afforested areas are included in the NFI and hence it is better to include them within the applied ratio. This is possible as no harvest is expected before 2020 in the AF category. After this date the harvest would have to be split between FM and AF.

Figure 11-25: projected and measured harvest rate



The harvest rate have strong year on year fluctuations which can obviously not be modelled. The harvest projections show that, in the long term, an increase in deciduous wood is compensated by a reduction in coniferous wood. This can be explained by the high proportion of old beech forests which have reached their maturity age. For coniferous forest recent legislation enabled the clearfelling of forest older than 50 years which lead to an increase in harvest. Hence a further significant increase in harvest from coniferous forests is not expected.

11.5.3.2.5 Projected emissions for Forest Management (activity-based approach)

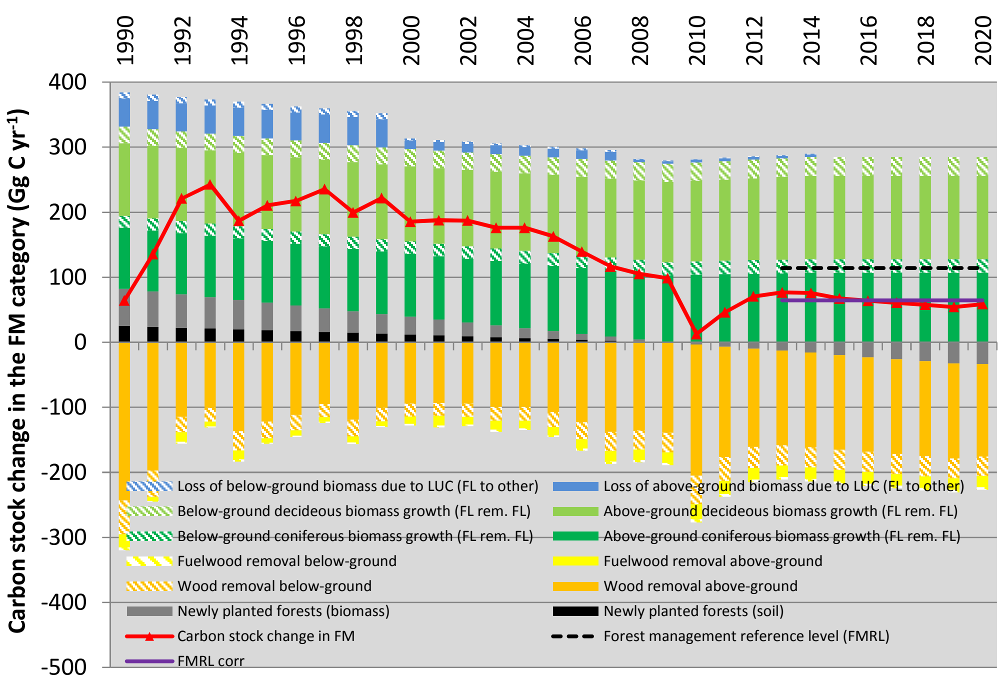
The definition of forest management according to KP comprises all forest minus the forest areas which have been afforested or reforested since 1990 (Luxembourg has not elected carbon equivalent forests). The calculation for biomass gain and loss as well as carbon gain and loss in soils according to GPG UNFCC differentiate between mature forests (older than 20 years) and forest that have been newly planted. Carbon stock changes of forests that have been planted between 1970 and 1990 have to be calculated separately within the forest management category. Areas included in the AR category remain in the AR category and do not transit to the FM category. Not even after a period of 20 years.

For established forests it is assumed that the carbon content of litter does not change. It is assumed that litter levels (default value of 19,6 tC/ha) are reached after a transition period of 20 years. Dead wood levels are also assumed to be constant apart from the period between 2000 and 2010 where the national forest inventory highlighted an increase in dead wood following a change in harvesting practices.

In order to avoid double accounting the biomass loss due to deforestation has been subtracted from the harvest figures.

11.5.3.2.6 Projected emissions for Forest Management (activity-based approach)

Figure 11-26: projected emissions in FM and FMRL corr.



The following points are important when analysing Figure 11-26:

a. Growth rate in forests are easy to predict and are more or less constant over the years. The harvest rate, on the other hand, has strong year on year fluctuations and is the strongest contributor to changes in emissions.
b. The emissions are based on the assumption that there is no afforestation or deforestation after 2013.
c. The wood removals, due to deforestation area, are reported under deforestation and are hence subtracted from the total wood removals. In order to do this they are reported as sinks in this chart and represented by the blue bars.
d. The projected emissions for the FM sector (as defined under KP) are calculated based on the emissions of the forestland remaining forestland (FL rem. FL) as submitted under UNFCCC. In order to convert the emissions from the category FL rem. FL to FM all emissions due to areas that have been afforested after 1990 (and are reported under afforestation under KP) have to be subtracted. This is shown in the figure by the grey bars.
e. Previous to 2010 the emissions, due to newly planted forests, are still positive as the biomass growth in areas that have been newly planted previous to 1990 (and reported under FM) outweigh the biomass growth of areas that have been afforested after 1990 and are reported under the afforestation category. (Biomass growth is calculated as biomass growth from FL remaining FL + biomass growth from other categories converted to FL – biomass growth of afforestation). Between 2010 and 2020 the removals due to the afforestation areas are increasing because growth rate for forest older than 20 years are higher than for younger ones. This has a strong influence when comparing the emission in FM to the FMRL (forest management reference level) represented by the black dotted line).
f. The average removals, for the years 2013-2020, calculated according to the estimates of this study amount to -64.45 $GgCyr^{-1}$.

Table 11-15: summary table of technical correction of FMRL

	Emissions and removals
FMRL	- 114 $GgCyr^{-1}$
$FMRL_{corr}$	- 64.45 $GgCyr^{-1}$
Difference in % = 100*[(FMRLcorr-FMRL)/FMRL]%	- 43%
Technical Correction = $FMRL_{corr}$-FMRL	49.55 $GgCyr^{-1}$
FM reported during the commitment period (2015)	- 83.58 $GgCyr^{-1}$
Accounting Parameter = reported FM – (FMRL + Technical Correction)	-19.13 $GgCyr^{-1}$

11.5.3.3 Provision for carbon equivalent forests

Luxembourg has not elected the provision for carbon equivalent forests.

11.5.3.4 Provision for natural disturbances

For the second commitment period, Luxembourg has decided to elect the provision for the treatment of natural disturbance emissions for FM under Article 3.4 and or AR under Article 3.3 as set out in the Annex to Decision 2/CMP.7. (According to Annex I to Decision 2/CMP.8, a Party's report to facilitate the calculation of the assigned amount pursuant to Article 3, paragraphs 7bis, 8 and 8bis *shall contain an indication of whether it intends to apply the provisions to exclude emissions from* *natural disturbances for the accounting for afforestation and reforestation under Article 3, paragraph 3, of the Kyoto Protocol and/or forest management under Article 3. paragraph 4, of the Kyoto Protocol during the second commitment period, in accordance with decision 2/CMP.7.*)

Luxembourg has developed a background level and a margin for natural disturbances according to the methodology described in IPCC KP Supplements (2014):

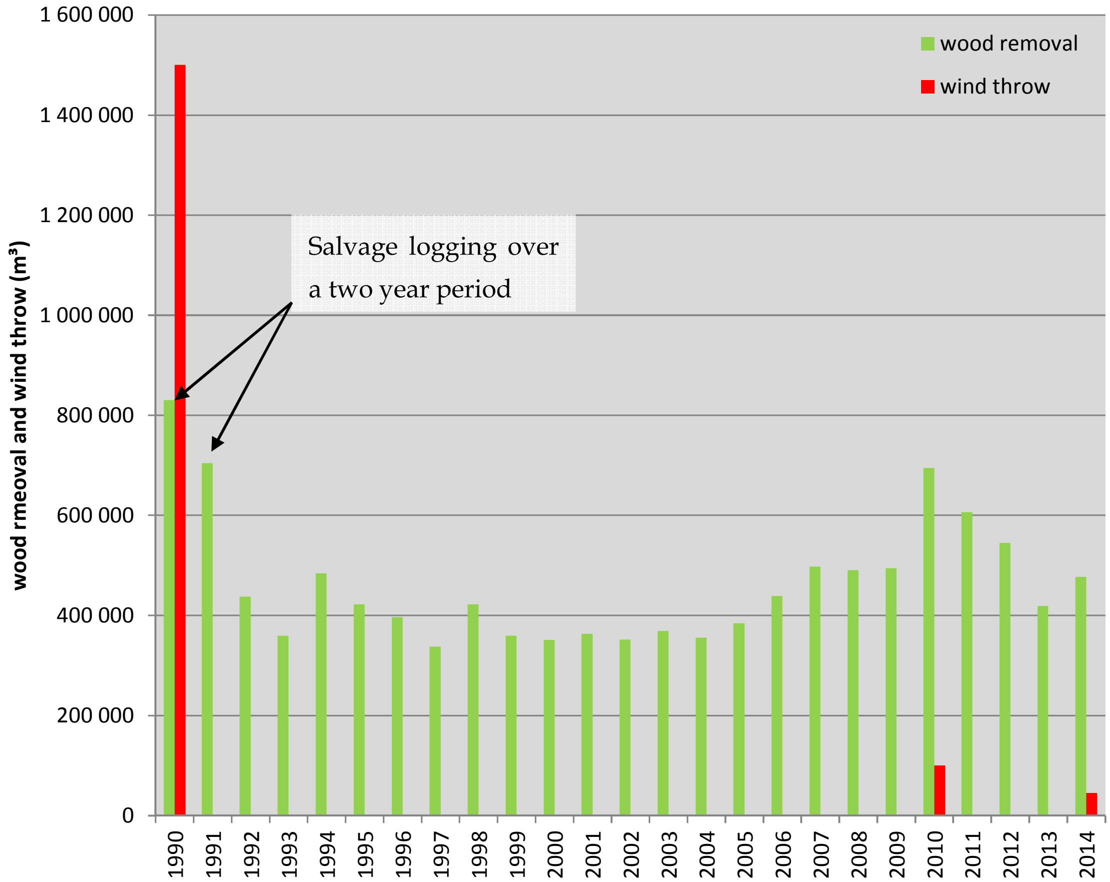
Step 1: Define the type of natural disturbances that the Party wishes to exclude from accounting:

Wildfires have occurred on some occasions but are very rare and the extent of wildfires have always been very limited. Insect attacks (eg bark beetle) do occur in Luxembourg but forest owners have an obligation to remove infected trees (salvage logging) in order to stem its propagation. The same principle applies to disease infestations (mainly fungal infestation like Fomes fomentarius and ash tree infestation). Ash tree infestation with Hymenoscyphus fraxineus is, as in many European countries, widespread in Luxembourg. Luxembourg does, however, not have a big ash tree population (+/- 1,3 %) and infestations are generally act on by removing trees (salvage logging).

Extreme weather events, like wind storm, on the other hand, can have wide reaching consequences for Luxembourg. Due to the small size of the country one major storm can have a severe impact on the total forest population in Luxembourg. Hence the definition of natural disturbances for Luxembourg will be limited to extreme weather events.

Step 2: Establish a consistent and initially complete time series of annual emissions for the calibration period for each disturbance type.

Figure 11-27 Data on wood removal and wood loss through wind storms



Data on wood loss due to wind storms are available for following storms: Viven, Wiebke (1990), Klaus (2009) and Xynthia (2010) and have been collected by the forest agency. Figure 11-27 is showing wood loss due to wind throw (red bars) as well as wood removal due to forest management (green bars). Wind storms do not occur on an annual basis and hence a number of years show zero emissions due to windstorms. The most severe windstorm was windstorm Viven, Wiebke in 1990. The following wood losses due to the wind storms in 2010 and 2014 were only minor. The data on wood removal highlights how, after the wind storm of 1990, salvage logging has been taking place over two years. In Luxembourg wood lost through the wind storms is in general salvaged. Emissions from and associated with salvage logging cannot be excluded from accounting during the commitment period and consequently historical emissions from natural disturbances should exclude emissions from salvage logging.

Step 3: Develop the background level using the default or alternative method: Due to the small number of natural disturbances over the course the analysed time series the default method cannot be used as the standard deviation is always greater than the mean average over the remaining values (and this by excluding one, two or all three values). An alternative method would set the background level to the minimum level of historical time series which is zero. Considering the small number of samples this seems to be the only method available.

Step 4: Develop the margin

The margin is twice the standard deviation excluding outliners. If the background level is set equal to zero then the margin is zero.

Step 5: Ensuring that the method applied does not lead to the expectation of net credits or net debts.

With a baseline of zero as well as a margin of zero it does not seem possible to achieve net credits or debts by accounting for natural disturbances.

To sum up, historical data shows that damage caused by wind storms is the major cause of natural disturbances. In the past, most wood lost has however been recovered through salvage logging and hence the provision for natural disturbances could not have been applied. It seems also unlikely that Luxembourg will apply the provision in the future. The provision has to be regarded more as a safeguard in case of major storm events might hit Luxembourg in the future and affect most of the forest areas.

11.5.3.5 Information about harvested wood products under Article 3.4

For Luxembourg, the wood harvest can be fully assigned to the two activities forest management and deforestation. Nevertheless due to the incomplete dataset on HWP (especially with regards to import and exports figures) all wood harvested for the production of HWP is considered as instantaneous oxidation. Further information, and details on the calculations carried out for Luxembourg, are provided in Chapters 6.8.

11.6 Other information

11.6.1 Key category analysis for Article 3.3 activities and any elected activities under Article 3.4

Afforestation and Reforestation, Deforestation, and Forest Management are considered key categories according to a quantitative analysis (Table 11-16). For further information on key category analysis please refer to section 1.5, and in particular Table 1-9.

Table 11-16 – Overview of key categories for LULUCF activities under the Kyoto Protocol (CRF – NIR 3 table)

KEY CATEGORIES OF EMISSIONS AND REMOVALS	Gas	CRITERIA USED FOR KEY CATEGORY IDENTIFICATION			Comments[4]
		Associated category in UNFCCC inventory[1] is key (indicate which category)	Category contribution is greater than the smallest category considered key in the UNFCCC inventory[2] (including LULUCF)	Other[3]	
Specify key categories according to the national level of disaggregation used[1]					
Afforestation and Reforestation					
CO2	CO2	Land converted to forest land	Yes	none	no comments
Deforestation					
CO2	CO2	grassland,Land converted to other land,Land converted to settlements,Land converted to wetlands	Yes	none	no comments
Forest Management					
CO2	CO2	Forest land remaining forest land	Yes	none	no comments

1.6.2 The calculations of the data for category 5 are verified as follows:

- Are the correct values used (check for transcription errors …)?
- Check of plausibility of input data (time-series, order of magnitude, values of neighbouring countries …)
- Is the data set complete for the whole time series?
- Check of calculations, units...
- Check of plausibility of results (time-series, order of magnitude, values of neighbouring countries …)
- Correct transformation/transcription into CRF
- Where possible, data is checked with data from other sources, order of magnitude checks …
- Are all references clearly made?
- Are all assumptions documented?

Consistency and completeness checks have been performed using the tools embedded in CRF Reporter.

11.7 Information related to Article 6

There are no Article 6 activities concerning the LULUCF sector in Luxembourg.

12 Information on accounting of Kyoto units

12.1 Background information

Annex I Parties are required to report from their national registry the holding and transactions of Kyoto units in the previous calendar year, i.e. 2016, and inform about related issues. The following chapters serve this purpose.

12.2 Summary of information reported in the SEF tables

The standard electronic format (SEF) for providing information on ERU's, CERs, tCERs, lCERs, AAUs and RMUs for the year 2016 was submitted to the UNFCCC on April 15th, 2017 (RREG1_LU_2016.xlsx) together with this report.

12.3 Discrepancies and notifications

Further information on KP units referring to the respective paragraphs of decision 15/CMP.1 is reported in the following list:

- Paragraph 12: No discrepant transactions occurred in 2016.
- Paragraph 13: No CDM notification occurred in 2016.
- Paragraph 14: No CDM notification occurred in 2016.
- Paragraph 15: No non-replacements occurred in 2016.
- Paragraph 16: No invalid units exist as of 31 December 2016.
- Paragraph 17: No actions were taken or changes made to address discrepancies for the period under review.

12.4 Publicly accessible information

The public reports can be consulted directly at:

https://ets-registry.webgate.ec.europa.eu/euregistry/LU/public/reports/publicReports.xhtml

Reports are provided according to Annex XVI of the Commission Regulation 2216/2004 amended by Regulation 916/2007, Regulation 994/2008 and Regulation 920/2010.

12.5 Calculation of the commitment period reserve (CPR)

In accordance with decision 11/CMP.1, paragraph 6, and decision 1/CMP.8, paragraph 18, 'each Party included in Annex I shall maintain, in its national registry, a commitment period reserve which should not drop below 90 per cent of the Party's assigned amount calculated pursuant to

Article 3(7) and (8) of the Kyoto Protocol, or 100 per cent of eight times its most recent inventory, whichever is lowest'. Luxembourg has interpreted the 'most recent inventory' as the year 2014 which was reviewed from 26th September to 1st October 2016 and was resubmitted to the UNFCCC on 22nd January 2017.

Therefore Luxembourg's commitment period reserve is calculated as follows[174]:

Either:

Luxembourg's Adjusted Assigned Amount x 90%

72 454 473 x 0.90 = 65 209 026 assigned amount units

Or:

2014 Total Emissions x Total years of the second commitment period

10 773 437 x 8 = 86 187 492 assigned amount units

Since the lower of the two numbers is the one corresponding to 90 per cent of Luxembourg's assigned amount, Luxembourg's Commitment Period Reserve is therefore *65 209 026 tonnes CO_2 eq.* (or assigned amount units).

12.6 KP-LULUCF accounting

Luxembourg selected accounting of the KP-LULUCF activities at the end of the commitment period.

12.7 FM cap

For the second commitment period, additions to the assigned amount of a Party resulting from forest management shall, in accordance with paragraph 13 of the annex to decision 2/CMP.7, not exceed 3.5 per cent of the national total emissions excluding LULUCF in the base year times eight.

Luxembourg has elected 1990 as a base year for its GHG emissions. For F-gases Luxembourg has however chosen 1995 as a base year and hence the calculation of the FM cap for the second commitment period corresponds to:

174 Luxembourg's Initial Report to facilitate the calculation of the assigned amount for the second commitment period – Update from March 15, 2017.
http://unfccc.int/national_reports/initial_reports_under_the_kyoto_protocol/second_commitment_period_2013-2020/items/9499.php

	Emissions and removals
Total CO_2 equivalent emissions without land use, land-use change and forestry (1990)	12730.46 kt CO2eq[175]
Emissions of HFCs and PFCs - 1990	0.0000715 kt CO2 eq
Emissions of HFCs and PFCs - 1995	18.306432 kt CO2 eq
Emissions of SF6 - 1990	0.876210 kt CO2 eq
Emissions of SF6 - 1995	1.389464 kt CO2 eq
FMcap = 0.035*(12730.46-0.8762-0.00007150+1.3894+18.306432)*8	**3569.8 kt CO2 eq** [175]

[175] These values have not been updated in the CRF Reporter. They will be updated for submission 2018.

13 Information on changes in national system

The national system is unchanged compared to the description given in the previous National Inventory Report.

14 Information on changes in national registry

The following changes to the national registry of Luxembourg have occurred in 2016:

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(a) Change of name or contact	None
15/CMP.1 annex II.E paragraph 32.(b) Change regarding cooperation arrangement	No change of cooperation arrangement occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(c) Change to database structure or the capacity of national registry	New tables were added to the CSEUR database for the implementation of the CP2 SEF functionality. Versions of the CSEUR released after 6.7.3 (the production version at the time of the last Chapter 14 submission) introduced other minor changes in the structure of the database. These changes were limited and only affected EU ETS functionality. No change was required to the database and application backup plan or to the disaster recovery plan. The database model, including the new tables, is provided in Annex A. No change to the capacity of the national registry occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(d) Change regarding conformance to technical standards	Changes introduced since version 6.7.3 of the national registry are listed in Annex B. Each release of the registry is subject to both regression testing and tests related to new functionality. These tests also include thorough testing against the DES and were successfully carried out prior to the relevant major release of the version to Production (see Annex B). Annex H testing was completed in January 2017 and the test report is provided. No other change in the registry's conformance to the technical standards occurred for the reported period.
15/CMP.1 annex II.E paragraph 32.(e) Change to discrepancies procedures	No change of discrepancies procedures occurred during the reported period.

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(f) Change regarding security	The mandatory use of hard tokens for authentication and signature was introduced for registry administrators.
15/CMP.1 annex II.E paragraph 32.(g) Change to list of publicly available information	No change to the list of publicly available information occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(h) Change of Internet address	No change of the registry internet address occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(i) Change regarding data integrity measures	No change of data integrity measures occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(j) Change regarding test results	Changes introduced since version 6.7.3 of the national registry are listed in Annex B. Both regression testing and tests on the new functionality were successfully carried out prior to release of the version to Production. The site acceptance test was carried out by quality assurance consultants on behalf of and assisted by the European Commission; the report is attached as Annex B. Annex H testing was carried out in January 2017 and the test report is provided.

15 Information on minimization of adverse impacts in accordance with Article 3, paragraph 14

-> No changes occurred since the last submission (NIR 2016) - ARR 2013, §88.

23. Each Party in Annex I shall provide information relating to how it is striving, under Article 3, paragraph 14, of the Kyoto Protocol, to implement its commitments mentioned in Article 3, paragraph 1 of the Kyoto Protocol in such a way as to minimize adverse social, environmental and economic impacts on developing country Parties, particularly those identified in Article 4, paragraphs 8 and 9, of the Convention.

The Kyoto Protocol is, in principle and in general, designed to minimize adverse effects on specific sectors, specific industries or specific trade partners of a Party, including the adverse effects of climate change, on international trade, and social, environmental and economic impacts on other parties. This is due to the fact that it does not limit action to a single gas or sector, that the use of its flexible mechanisms garantees that possible impacts are distributed on various fields of action, that the Clean Development Mechanism aims at both promoting sustainable development in countries with continuing development needs and at reducing greenhouse gas emissions, and that it requests action to support the least developed countries. By striving to implement all the features that the Protocol has integrated Luxembourg is naturally working to minimize not only adverse effects of climate change but also any adverse effects due to the reduction of greenhouse gases.

Luxembourg is strongly promoting long term sustainable development and will hence have scarcely direct or indirect negative effects. In cases where adverse effects could occur, the following measures are/were undertaken:

Adverse effects of climate change

Emission Trading could lead to carbon leakage and higher emissions in countries which do not have comparable environmental standards. To minimise that risk, according to EU Directive 2003/87/EC emission allowances are granted for free to companies with specific characteristics.

Social, environmental and economic impacts on developing countries

JI/CDM projects may in principle have negative side effects in the host countries. For example, projects for the production of biofuels might add to deforestation of forests and/or result in higher prices for food. Luxembourg's JI/CDM programme therefore has demanding social and environmental criteria to be eligible as a Luxembourgish JI/CDM project. The favoured project categories reflect the high priority that is given to technology transfer projects.

(http://ec.europa.eu/environment/climat/pdf/lux_nap_final.pdf/)

Ensuring that any consequences of economic affairs are addressed, Luxembourg is improving its policies to eliminate potential negative impacts.

24. Parties included in Annex II, and other Parties included in Annex I that are in the position to do so, shall incorporate information on how they give priority, in implementing their commitments under Article 3, paragraph 14, to the following actions, based on relevant methodologies referred to in paragraph 11 of decision 31/CMP.1

(a) The progressive reduction or phasing out of market imperfections, fiscal incentives, tax and duty exemptions and subsidies in all greenhouse-gas-emitting sectors, taking into account the need for energy price reforms to reflect market prices and externalities.

<u>Market imperfections:</u>

Luxembourg has reformed its energy markets to a large extent to reduce market imperfections and in order to comply with European legislation:

- Directive 2003/54/EC of the European Parliament and of the Council of 26 June 2003 concerning common rules for the internal market in electricity and repealing Directive 96/92EC.
- Directive 2003/55/EC of the European Parliament and of the Council of 26 June 2003 concerning common rules for the internal market in natural gas and repealing Directive 98/30EC.
- Council Directive 90/377/EEC of the 29 June 1990 concerning a Community procedure to improve the transparency of gas and electricity prices charged to industrial end-users.
- Regulation (EC) No 1228/2003 of the European Parliament and of the Council of 26 June 2003 on conditions of access to the network for cross-border exchanges in electricity.
- Directive 2004/17/EC of the European Parliament and of the Council of 31 March 2004 coordinating the procurement procedures of entities operating in the water, energy, transport and postal services sectors.

<u>Fiscal incentives:</u>

Several fiscal incentives have been put in place, aiming at reducing the use of fossil fuels:

- vehicle tax reform (RGD 22 december 2006): the tax is based on CO_2 emissions from road vehicles.
- raising excise duties on fuels for transport purposes: By the 1st of january 2007, the exise rate on gasoline was increased by 2ct€/litre. For diesel, the

excise rate was increased in two stages: 1.25ct€/litre on 1.1.2007, and by a further 1.25 cte/litre on 1.1.2008. This autonomous addition to the existing excise rates is used to finance the Kyoto funf set up in Luxembourg to deal with the Kyoto "flexible mechanisms" and is labled "climate change contribution". Indeed, increasing excise rates on road fuels lead to an increase of fuel retail prices and thus, set an incentive for consumers to lower demand.

Subsidies:

Several subsidies have been put in place in the residential, commercial and institutional sectors, aiming at reducing the use of fossil fuels:

- promotion of energy efficiency and the use of renewable energy sources in the residential sector (solar heaters, heat pumps, photovoltaics, biomass boilers and wood stoves).
- program encouraging refurbishment of existing residential buildings to increase energy efficiency.
- program encouraging the construction of highly energy efficient residential buildings.
- establishment of an energy pass certifying the energy class of residential, commercial and institutional buildings.
- promoting low energy electrical appliances.

(b) Removing subsidies associated with the use of environmentally unsound and unsafe technologies.

So far, no subsidies for environmentally unsound technologies have been identified.

(c) Cooperating in the technological development of non-energy uses of fossil fuels, and supporting developing country Parties to this end.

This technological field is not a high priority in Luxembourg's research policy.

(d) Cooperating in the development, diffusion and transfer of less-greenhouse-gasemitting advanced fossil-fuel technologies, and/or technologies, relating to fossil fuels, that capture and store greenhouse gases, and encouraging their wider use; and facilitating the participation of the least developed countries and other non-Annex I Parties in this effort.

(e) Strengthening the capacity of developing country Parties identified in Article 4, paragraphs 8 and 9, of the Convention for improving efficiency in upstream and downstream activities relating to fossil fuels, taking into consideration the need to improve the environmental efficiency of these activities.

(f) Assisting developing county Parties which are highly dependent on the export and consumption of fossil fuels in diversifying their economies.

For (d) to (e) please refer to Luxembourg's 5th national communication, p.236-240.

16 Other information

n/a

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