



LE GOUVERNEMENT  
DU GRAND-DUCHÉ DE LUXEMBOURG  
Ministère du Développement durable  
et des Infrastructures

Administration de l'environnement

# Luxembourg's National Inventory Report 1990-2014

*In 2015, Luxembourg made an inventory submission under UNFCCC, but not under the Kyoto Protocol because the CRF Reporter could not deliver CRF tables for Kyoto Protocol LULUCF activities without errors. The present report is the official inventory submission of Luxembourg for the year 2016 under the UNFCCC and for the years 2015 and 2016 under the Kyoto Protocol, in spite of the remaining deficiencies in the CRF Reporter and underlying CRF tables. Luxembourg should not be held liable for errors caused by the CRF Reporter in the review of the submitted information. The inventory data reported in the 2015 submission under the UNFCCC have been revised in this submission. Therefore, the 2016 submission should also be considered as a resubmission of the estimates with regard to the 2015 UNFCCC submission.*

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## ***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 2014, Luxembourg's greenhouse gas emissions amounted to a total of 10.771 million tonnes calculated in CO<sub>2</sub> equivalents (CO<sub>2</sub>e) – excluding land-use, land-use change and forestry (LULUCF). Carbon dioxide (CO<sub>2</sub>) was the main source of greenhouse gases (GHG) in Luxembourg (Table 0-1). This source counted for 90.85% of the total GHG emissions (excluding LULUCF). The second source of GHG was methane (CH<sub>4</sub>) with about 5.53% of the total emissions excluding LULUCF. Nitrous oxide (N<sub>2</sub>O) was the third source with 2.90%. Fluorinated gases (*F-gases*) only accounted for 0.72% of the total emissions excluding LULUCF, with hydrofluorocarbons (HFCs) representing 0.64%, and sulphur hexafluoride (SF<sub>6</sub>) representing 0.08% of the national total (excl. LULUCF).

In 2014, total GHG emissions decreased by 3.90% compared to 2014 and 16.32% below their base year level <sup>1</sup>. For the different GHG, trends over the period 1990-2014 (and 2013-2014) were as follows:

- CO<sub>2</sub>: ..... -17.82% (-4.61%)
- CH<sub>4</sub>: ..... -8.01% (+1.20%)
- N<sub>2</sub>O: ..... +2.51% (+9.86%)
- F-gases: ..... +286.25%<sup>2</sup> (+6.05%)

Carbon dioxide emissions, over the period 1990-2014, 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 5.2% compared to 2009. However, since 2005 emissions have decreased by 19.1%.

Methane emissions have declined over the period due to the conjunction of reduced methane emissions in waste management (-56.1%) and in agriculture (-1.9%) and increasing emissions in energy use (+18.0%), 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 269% in 2014 compared to the base year (1995), whereas SF<sub>6</sub> emissions showed an 8.5-fold increase between 1995 and 2014.

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 10.310 million tonnes CO<sub>2</sub> eq (incl. LULUCF). Net removals from the LULUCF sector amounted to 460.4 Gg CO<sub>2</sub> eq. Since 1990, net emissions have decreased by 983% per cent (the sector was a source of net emissions in 1990 (52.13 Gg CO<sub>2</sub> eq) and a source of net removals in 2014).

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<sup>1</sup> The base year for CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O is 1990. For the F-gases, the base year is 1995.

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



### ES.2.2. KP-LULUCF activities

In 2014, Article 3.3 activities were a net sink in Luxembourg and net CO<sub>2</sub> removals amounted to 134.14 Gg CO<sub>2</sub>e. Removals from afforestation/reforestation amounted to 176.28 Gg CO<sub>2</sub>. 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 afforestation/reforestation (AR) areas. In the same year, emissions from deforestation amounted to 42.14 Gg CO<sub>2</sub>. 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<sub>2</sub> removals amounted to 359.7 Gg CO<sub>2</sub>e. By taking into account the FMRL of 418 Gg CO<sub>2</sub>e, the activity forest management becomes a net source of 58.3 Gg CO<sub>2</sub>e. 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 2014, the energy sector accounted for almost 87.30% 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 (6.00%) and agriculture (6.24%). The remaining sectors<sup>3</sup> (LULUCF (4.27%), waste<sup>4</sup> (0.46%) and other (NA)) were not even reaching over 4.5% of the total GHG emitted in Luxembourg.

For the different sectors, trends over the period 1990-2014 (and 2013-2014) were as follows:

• Energy: .....	-9.68%	(-4.90%)
• Industrial processes & product use: ..	-60.83%	(+5.92%)
• Agriculture: .....	-6.03%	(+1.86%)
• LULUCF:.....	-983.21%	(-14.51%)
• Waste: .....	-48.13%	(-1.89%)
• Other: .....	NA	

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<sup>3</sup> The sector "other" is not reported for Luxembourg.

<sup>4</sup> 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 81% to 87% over the period 1990 to 2014. 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): +1924% and +127%, respectively between 1990 and 2014 +5.15% and -4.3% from 2013 to 2014) with, as a result, a share in the total energy related GHG emissions rising from 0.28% to 6.70% and 20.9% to 56.6%, respectively. For the other sub-sectors, the observed trends between 1990 and 2014 are -82.7% for manufacturing industries (1A2), +9.3% for the other sectors (1A4), and +98.5% for fugitive emissions from fuels (1B).<sup>5</sup>

The **third** largest sector in Luxembourg with regard to 2014 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 90% since 1990. Compared to 2013, emissions from industrial processes and product use increased by 5.9% in 2014, which is mainly due to an increase in F-gas emissions in the category 2.G.- *Other product manufacture and use*.



<sup>5</sup> Fugitive emission growth is closely linked to natural gas use in Luxembourg.

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.

### **ES.3.2. KP-LULUCF activities**

In 2014, Article 3.3 activities were a net sink in Luxembourg and net CO<sub>2</sub> removals amounted to 134.14 Gg CO<sub>2</sub>e. CO<sub>2</sub> removals from Aforestation/Reforestation (AR) in Luxembourg amounted to 176.28 Gg CO<sub>2</sub>. 119.13 Gg CO<sub>2</sub> resulted from an increase in above- and belowground biomass, 5.45 Gg CO<sub>2</sub> from dead wood, 18.61 Gg CO<sub>2</sub> from litter and 33.09 Gg CO<sub>2</sub> from soil carbon. Emissions from Deforestation (D) activities were approximately 42.14 Gg CO<sub>2</sub>e in 2014. 17.00 Gg CO<sub>2</sub> resulted from a loss in above- and belowground biomass, 0.81 Gg CO<sub>2</sub> from dead wood, 2.77 Gg CO<sub>2</sub> from litter and 21.20 Gg CO<sub>2</sub> from soil carbon. N<sub>2</sub>O emissions from disturbance associated with land use conversion to cropland amounted to 0.36 Gg CO<sub>2</sub>e.

Under Article 3.4, Luxembourg is reporting emissions of 58.3 Gg CO<sub>2</sub>e in the year 2014. This corresponds to a fourfold increase compared to the figures from 2013, where the activity of forest management was a net sink. This decrease in CO<sub>2</sub> removals can be solely attributed to an increase of wood harvested in 2014.

### ***ES.4. Other information: Emission Estimates and Trends of Indirect GHG and SO<sub>2</sub>***

Some indirect GHG – NO<sub>x</sub>, CO, NMVOCs – and SO<sub>2</sub> 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 related 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](http://www.ceip.at/ms/ceip_home1/ceip_home/status_reporting)

**Table 0-1 – Luxembourg's GHG emissions and removals – overview by main gases: 1990-2014**

Gg (1000 t) CO <sub>2</sub> eq	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
CO <sub>2</sub>	11961.50 92.93%	12487.28 93.07%	12269.88 93.00%	12392.33 93.11%	11578.79 92.80%	9174.05 90.93%	9236.43 90.90%	8551.85 90.24%	7640.24 89.19%	8007.56 89.62%	8819.12 90.52%	9331.52 91.08%	10088.77 91.66%	10464.78 92.06%	11891.92 92.84%	12150.18 93.14%	12012.04 93.13%	11414.96 92.70%	11258.43 92.52%	10740.17 92.19%	11294.32 92.42%	11179.89 92.46%	10882.32 92.44%	10305.28 91.95%	9829.93 91.27%
CH <sub>4</sub> (1)	619.80 4.62%	626.98 4.67%	616.94 4.68%	615.90 4.63%	597.71 4.79%	610.49 6.05%	616.39 6.07%	613.87 6.48%	609.06 7.11%	612.21 6.85%	604.65 6.21%	604.11 5.90%	601.27 5.46%	587.29 5.17%	581.06 4.94%	577.28 4.43%	571.85 4.43%	581.27 4.72%	588.27 4.83%	588.39 5.05%	597.34 4.89%	571.20 4.72%	559.23 4.73%	563.36 5.03%	570.12 5.29%
N <sub>2</sub> O (2)	288.77 2.24%	301.41 2.25%	291.20 2.21%	285.21 2.14%	283.13 2.27%	285.39 2.83%	286.55 2.82%	286.93 3.03%	290.33 3.39%	287.48 3.22%	287.95 2.96%	274.38 2.68%	278.04 2.53%	273.07 2.40%	292.26 2.28%	274.12 2.10%	267.76 2.08%	265.60 2.16%	267.23 2.20%	265.18 2.28%	270.34 2.21%	277.86 2.30%	265.07 2.25%	269.44 2.40%	296.01 2.75%
HFCs (3)	0.00 0.00%	0.00 0.00%	13.68 0.10%	14.70 0.11%	15.98 0.13%	17.90 0.18%	19.63 0.19%	22.05 0.23%	24.45 0.29%	26.25 0.29%	28.98 0.30%	32.85 0.32%	35.65 0.32%	37.93 0.33%	39.99 0.31%	38.99 0.30%	41.88 0.32%	46.46 0.38%	48.81 0.40%	49.67 0.43%	52.33 0.43%	55.19 0.46%	57.53 0.49%	61.17 0.55%	66.08 0.61%
PFCs (3)	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	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA
SF <sub>6</sub> (3)	0.88 0.01%	0.98 0.01%	1.08 0.01%	1.19 0.01%	1.30 0.01%	1.39 0.01%	1.56 0.02%	1.70 0.02%	1.74 0.02%	1.83 0.02%	1.93 0.02%	2.54 0.02%	3.15 0.03%	3.73 0.03%	4.28 0.03%	4.85 0.04%	5.27 0.04%	5.69 0.05%	6.10 0.05%	6.49 0.06%	6.87 0.06%	7.31 0.06%	7.68 0.07%	8.05 0.07%	8.44 0.08%
<b>Total GHG excluding LULUCF</b>	<b>12870.95</b> 100.00%	<b>13416.64</b> 100.00%	<b>13192.78</b> 100.00%	<b>13309.33</b> 100.00%	<b>12476.91</b> 100.00%	<b>10089.23</b> 100.00%	<b>10160.56</b> 100.00%	<b>9476.40</b> 100.00%	<b>8565.82</b> 100.00%	<b>8935.33</b> 100.00%	<b>9742.63</b> 100.00%	<b>10245.40</b> 100.00%	<b>11006.87</b> 100.00%	<b>11366.81</b> 100.00%	<b>12809.52</b> 100.00%	<b>13045.43</b> 100.00%	<b>12898.80</b> 100.00%	<b>12313.97</b> 100.00%	<b>12168.84</b> 100.00%	<b>11649.91</b> 100.00%	<b>12221.20</b> 100.00%	<b>12091.45</b> 100.00%	<b>11771.84</b> 100.00%	<b>11207.30</b> 100.00%	<b>10770.58</b> 100.00%

Source: Environment Agency

Notes:

(1) The methane emissions are converted in CO<sub>2</sub> 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<sub>2</sub> 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<sub>6</sub> expressed in CO<sub>2</sub> 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: 1990-2014**

Gg (1000 t) CO <sub>2</sub> eq	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
1. Energy	10411.19 80.89%	11023.26 82.16%	10880.79 82.48%	11026.95 82.85%	10306.93 82.61%	8260.47 81.67%	8383.56 82.51%	7810.85 82.42%	7060.30 82.42%	7387.73 82.68%	8177.38 83.93%	8753.33 86.44%	9510.65 86.41%	9953.48 87.57%	11330.11 88.45%	11607.81 88.96%	11416.04 88.90%	10820.78 87.87%	10724.94 88.13%	10271.69 88.17%	10817.32 88.51%	10680.15 88.33%	10445.09 88.73%	9887.16 88.22%	9403.04 87.30%
2. Industrial Processes	1648.46 12.81%	1589.57 11.70%	1511.54 11.46%	1488.78 11.19%	1396.74 11.19%	1037.03 10.28%	982.46 9.67%	874.91 9.22%	716.82 8.37%	754.93 8.45%	782.33 8.03%	729.01 7.12%	748.76 6.80%	697.85 6.14%	755.79 5.90%	727.43 5.58%	782.97 6.07%	786.10 6.34%	720.22 5.92%	652.70 5.60%	672.53 5.50%	690.52 5.71%	631.40 5.36%	609.68 5.44%	645.78 6.00%
3. Agriculture	715.22 5.56%	725.73 5.41%	701.91 5.32%	695.02 5.22%	677.13 5.43%	698.52 6.92%	704.81 6.94%	701.18 7.40%	699.73 8.17%	705.71 7.90%	696.35 7.15%	682.24 6.66%	668.36 6.07%	634.70 5.58%	648.36 5.06%	637.12 4.86%	628.56 5.22%	642.69 5.40%	656.65 5.67%	660.21 5.48%	669.54 5.48%	663.39 5.49%	643.96 5.47%	659.66 5.89%	671.93 6.24%
4. Land use, land-use change and forestry	52.13 0.41%	-225.11 -1.68%	-554.29 -4.20%	-649.35 -4.88%	-460.17 -3.69%	-563.24 -5.58%	-603.66 -5.94%	-686.40 -7.24%	-570.82 -6.66%	-668.53 -7.48%	-701.85 -7.20%	-714.13 -6.97%	-716.11 -6.51%	-679.32 -5.98%	-683.66 -5.34%	-638.66 -4.90%	-557.18 -4.32%	-477.85 -3.88%	-491.99 -4.04%	-469.41 -4.03%	-152.97 -1.25%	-274.98 -2.27%	-362.88 -3.08%	-538.62 -4.81%	-460.44 -4.27%
5. Waste	96.08 NA	98.10 NA	96.54 NA	98.58 NA	96.10 NA	93.22 NA	89.72 NA	89.45 NA	88.97 NA	86.95 NA	86.57 NA	80.82 NA	79.11 NA	80.79 NA	75.26 NA	73.07 NA	71.22 NA	70.39 NA	67.03 NA	65.31 NA	61.81 NA	57.39 NA	51.40 NA	50.79 NA	49.83 NA
6. Other	NA 0.00%	NA 0.00%	NA 0.00%	NA 0.00%	NA 0.00%	NA 0.00%	NA 0.00%	NA 0.00%	NA 0.00%	NA 0.00%	NA 0.00%	NA 0.00%	NA 0.00%	NA 0.00%	NA 0.00%	NA 0.00%	NA 0.00%	NA 0.00%	NA 0.00%	NA 0.00%	NA 0.00%	NA 0.00%	NA 0.00%	NA 0.00%	NA 0.00%
<b>Total GHG including LULUCF</b>	<b>12923.08</b> 100.00%	<b>13191.54</b> 100.00%	<b>12638.49</b> 100.00%	<b>12659.98</b> 100.00%	<b>12016.74</b> 100.00%	<b>9525.99</b> 100.00%	<b>9556.90</b> 100.00%	<b>8790.00</b> 100.00%	<b>7995.01</b> 100.00%	<b>8266.80</b> 100.00%	<b>9040.78</b> 100.00%	<b>9531.28</b> 100.00%	<b>10290.77</b> 100.00%	<b>10687.49</b> 100.00%	<b>12125.85</b> 100.00%	<b>12406.77</b> 100.00%	<b>12341.62</b> 100.00%	<b>11836.12</b> 100.00%	<b>11676.85</b> 100.00%	<b>11180.50</b> 100.00%	<b>12068.22</b> 100.00%	<b>11816.47</b> 100.00%	<b>11408.96</b> 100.00%	<b>10668.68</b> 100.00%	<b>10310.14</b> 100.00%
<b>Total GHG excluding LULUCF</b>	<b>12870.95</b> 100.00%	<b>13416.64</b> 100.00%	<b>13192.78</b> 100.00%	<b>13309.33</b> 100.00%	<b>12476.91</b> 100.00%	<b>10089.23</b> 100.00%	<b>10160.56</b> 100.00%	<b>9476.40</b> 100.00%	<b>8565.82</b> 100.00%	<b>8935.33</b> 100.00%	<b>9742.63</b> 100.00%	<b>10245.40</b> 100.00%	<b>11006.87</b> 100.00%	<b>11366.81</b> 100.00%	<b>12809.52</b> 100.00%	<b>13045.43</b> 100.00%	<b>12898.80</b> 100.00%	<b>12313.97</b> 100.00%	<b>12168.84</b> 100.00%	<b>11649.91</b> 100.00%	<b>12221.20</b> 100.00%	<b>12091.45</b> 100.00%	<b>11771.84</b> 100.00%	<b>11207.30</b> 100.00%	<b>10770.58</b> 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  $0.74 \pm 0.18$  °C between the start and the end of the 20<sup>th</sup> century<sup>6</sup>. The Intergovernmental Panel on Climate Change (IPCC) concludes that most of the observed temperature increases since the middle of the 20<sup>th</sup> 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 21<sup>st</sup> 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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<sup>6</sup> 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 21<sup>st</sup> century, annual mean temperatures are comprised between 9.3°C (2001) and 11.3°C (2007), 10.1°C in 2013. 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<sup>2</sup>) 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<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O) as well as hydrogenated fluorocarbons (HFCs), perfluorated halocarbons (PFCs), sulphur hexafluoride (SF<sub>6</sub>) and nitrogen trifluoride (NF<sub>3</sub>).

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 29<sup>th</sup> April 1998, and ratified the protocol on 31<sup>st</sup> 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 Assigned 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 transparency of the inventory.

Responsible for the preparation of Luxembourg's National Greenhouse Gas Inventory as well as the preparation of the NIR is the Air and Noise Division 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 2015.<sup>7</sup> It is based on data submitted to the UNFCCC in the Common Reporting Format (CRF) on 15<sup>th</sup> April 2016: submission 2016v1.<sup>8</sup> Besides being a submission under the UNFCCC, submission 2016v1 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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<sup>7</sup> Luxembourg's National Inventory Report dated 15 April 2015 (covering inventory years 1990 to 2013)

<sup>8</sup> Submission 2016v1 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/envvukika/](http://cdr.eionet.europa.eu/lu/eu/mmr/art07_inventory/ghg_inventory/envvukika/);

b) The UNFCCC web site: [http://unfccc.int/national\\_reports/annex\\_i\\_ghg\\_inventories/national\\_inventories\\_submissions/items/8812.php](http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/8812.php).



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

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 2016 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:	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 9 & 10:	Marc Schuman
Chapter 11:	Tim Mirgain with the help of Willibald Croi and Peter Weiss (UBA Vienna);
Chapters 12 - 14:	Martine Kemmer, Nora Becker
Chapters 15 & 16:	Marc Schuman

The GHG inventory reviewed in the present NIR covers the period 1990-2014 and contains information on anthropogenic emissions by sources and removals by sinks for direct GHG (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, HFCs, PFCs, SF<sub>6</sub> and NF<sub>3</sub>). With regard to indirect greenhouse gases (CO, NO<sub>x</sub>, NMVOCs) and SO<sub>2</sub>, though also recorded in this inventory, they are derived from the air pollutant emission inventory Luxembourg is compiling for the United Nations Economic Commission for Europe's Convention on Long-Range Transboundary Air Pollution (UN-ECE CLRTAP). Consequently, indirect GHG and SO<sub>2</sub> 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

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

<sup>10</sup> 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](http://unfccc.int/files/national_reports/annex_i_ghg_inventories/reporting_requirements/application/pdf/annotated_nir_outline.pdf)

and its related Informative Inventory report, which are both published on the Center on Emission Inventories and Projections website<sup>11</sup>.

### **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 Afforestation/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.<sup>12</sup>

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 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

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<sup>11</sup> [http://www.ceip.at/ms/ceip\\_home1/ceip\\_home/status\\_reporting](http://www.ceip.at/ms/ceip_home1/ceip_home/status_reporting)

<sup>12</sup> Luxembourg's initial report under the Kyoto Protocol for the second commitment period (2013-2020) is under preparation.

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:
  - 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);
  - 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);

- 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;
- Decision 11/CP.4 - National communications from Parties included in Annex I to the Convention;
- 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).
- 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<sub>2</sub>, NO<sub>x</sub>, NMVOCs, NH<sub>3</sub>, CO, TSP, PM<sub>10</sub>, and PM<sub>2.5</sub> 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<sub>2</sub>, NO<sub>x</sub>, NMVOCs and NH<sub>3</sub>;
- 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<sub>2</sub> 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<sup>13</sup> 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*)<sup>14</sup> 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).

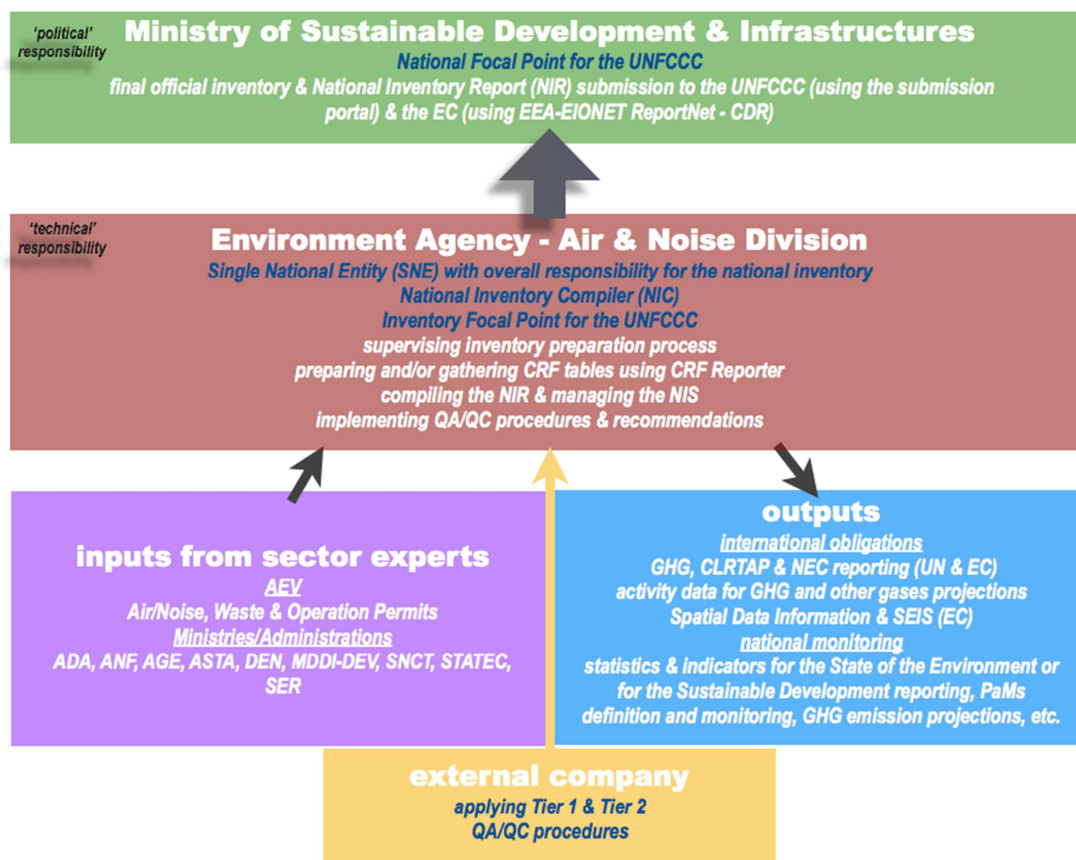
Figure 1-1 summarizes the organization of the GHG reporting in Luxembourg in accordance with the national Regulation for the setting-up of a National Inventory System (NIS).

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<sup>13</sup> Règlement grand-ducal du 1<sup>er</sup> 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>.

<sup>14</sup> 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](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](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 1<sup>st</sup> August 2007



It is worth noting that the Air/Noise Division 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<sub>2</sub> 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 Air/Noise Division of 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,

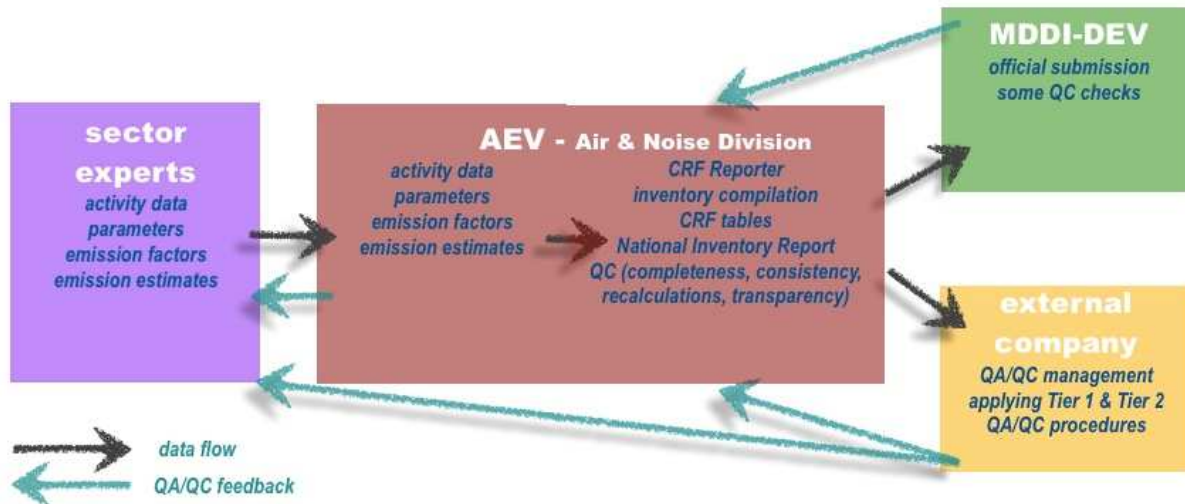
too, valuable information for the inventories is found. More details on these AD and, sometimes, EF sources are presented in Section 1.4.

With regards to outputs from the Air/Noise Division, 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<sup>15</sup>) and under the Shared Environmental Information System.<sup>16</sup> 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 Air/Noise Division 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

<sup>15</sup> See <http://inspire.jrc.it/>

<sup>16</sup> 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 Air/Noise Division, the quality manager, and the national inventory compiler.

During the meeting, the quality manager 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 Air/Noise division, 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 compiler; 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.<sup>17</sup>

### **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 2014 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<sup>18</sup>;
- the 2013 Revised Supplementary Methods and Good Practice Guidance 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.

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

<sup>18</sup> <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

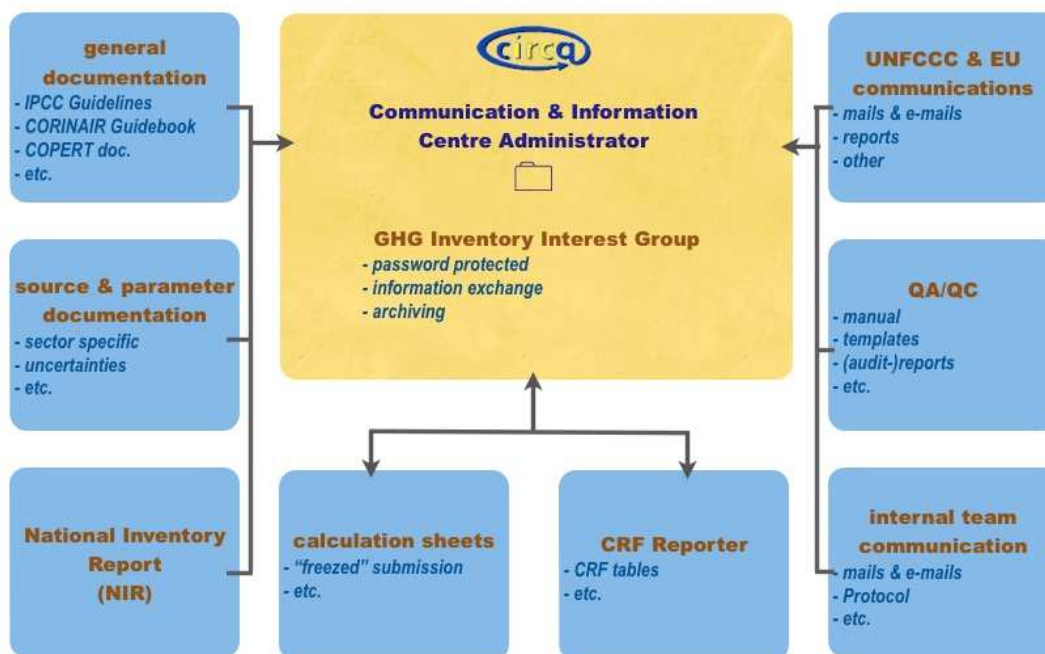
This way of proceeding offers a very flexible system that can be easily adjusted to new requirements. It is only for the estimation of road transportation emissions, where a dedicated model is used:

*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<sub>2</sub>, CO, CH<sub>4</sub>, NO<sub>x</sub>, VOC, and PM) and several more (N<sub>2</sub>O, NH<sub>3</sub>, SO<sub>2</sub>...). 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<sup>19</sup>. 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 <sub>2</sub>			CH <sub>4</sub>			N <sub>2</sub> O		
	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

<sup>19</sup> 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, <i>Emissionskataster für das Großherzogtum Luxemburg</i> , 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 developed 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<sup>20</sup>), 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<sup>21</sup>;
- 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

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<sup>20</sup> 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: Division Air/Bruit, Division des Déchets, Division des Établissements Classés, Registre national des quotas d'émission de gaz à effet de serre du Luxembourg ;
- 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 energy balance follows the International Energy Agency (IEA) and Eurostat conventions. The aggregated balances are harmonised with the IEA tables.

<sup>21</sup> <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*”<sup>22</sup> 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.<sup>23</sup> 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<sup>24</sup> 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 Administration 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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<sup>22</sup> See [http://www.environnement.public.lu/etablissements\\_classes/index.html](http://www.environnement.public.lu/etablissements_classes/index.html) (in French).

<sup>23</sup> “Permitting activities”, *i.e.* activities subordinated to a permit.

<sup>24</sup> <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 0.

## 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 significant 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. Actually, 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 in order 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<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, HFC, PFC and SF<sub>6</sub>, and all IPCC categories.

The key category analysis was performed using the Tier 1 approach on the basis of submission 2016v1. It comprises a level assessment for all years between 1990 and 2014, as well as a trend assessment for the trend of the year 2014 with respect to base year emissions, *i.e.* 1990 (1995 for F-gases). Key categories have been first identified excluding LULUCF categories and then repeated 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 and Table 1-8. The key categories without LULUCF comprise 10255.37 Gg CO<sub>2</sub>e in the year 2014, which is a share of 95.22% of Luxembourg's total GHG emissions, excluding LULUCF.

**Table 1-6 – Key categories (Tier 1, LA) excluding LULUCF based on emission data recorded in submission 2016v1**

IPCC	IPCC source category	Fuel	Gas	2014 emissions in Gg CO <sub>2</sub> e	Share in 2014 national total GHG emissions (excl. LULUCF)
1A1	Fuel combustion - Energy industries	gaseous	CO <sub>2</sub>	653.89	6.07%

1A1	Fuel combustion - Energy industries	other	CO <sub>2</sub>	62.30	0.58%
1A2	Fuel combustion – Manufacturing industries and construction	gaseous	CO <sub>2</sub>	689.09	6.40%
1A2	Fuel combustion – Manufacturing industries and construction	solid	CO <sub>2</sub>	183.94	1.71%
1A2	Fuel combustion – Manufacturing industries and construction	liquid	CO <sub>2</sub>	155.06	1.44%
1A3b	Fuel combustion – Transport - Road transportation	diesel oil	CO <sub>2</sub>	5082.52	47.19%
1A3b	Fuel combustion – Transport - Road transportation	gasoline	CO <sub>2</sub>	945.94	8.78%
1A4	Fuel combustion – Other sectors	gaseous	CO <sub>2</sub>	770.75	7.16%
1A4	Fuel combustion – Other sectors	liquid	CO <sub>2</sub>	665.67	6.18%
2A1	Cement production		CO <sub>2</sub>	353.79	3.28%
2A3	Glass production		CO <sub>2</sub>	61.07	0.57%
2C1	Iron and steel production		CO <sub>2</sub>	102.46	0.95%
3A	Enteric fermentation		CH <sub>4</sub>	415.90	3.86%
3D1	Agricultural soils - direct N <sub>2</sub> O emissions from managed soils		N <sub>2</sub> O	113.00	1.05%
<b>All</b>	<b>Sum of all key categories</b>	<b>all</b>	<b>all</b>	<b>10255.37</b>	<b>95.22%</b>

Table 1-7 indicates which source categories have been identified as key categories (LA) for every reported year from 1990 to 2014.

**Table 1-7 – Key categories (Tier 1, LA) excluding LULUCF of submission 2016v1: 1990-2014**

IPCC source category	source code	fuel	Gas	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
Fuel combustion - Energy industries	1A1	gaseous	CO <sub>2</sub>												X	X	X	X	X	X	X	X	X	X	X	X	X	X
Fuel combustion - Energy industries	1A1	other	CO <sub>2</sub>									X	X			X					X	X	X	X	X	X	X	X
Fuel combustion – Manufacturing industries and construction	1A2	liquid	CO <sub>2</sub>	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
Fuel combustion – Manufacturing industries and construction	1A2	solid	CO <sub>2</sub>	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
Fuel combustion – Manufacturing industries and construction	1A2	gaseous	CO <sub>2</sub>	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
Fuel combustion – Transport - Road transportation	1A3b	gasoline	CO <sub>2</sub>	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
Fuel combustion – Transport - Road transportation	1A3b	diesel oil	CO <sub>2</sub>	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
Fuel combustion – Other sectors	1A4	liquid	CO <sub>2</sub>	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
Fuel combustion – Other sectors	1A4	gaseous	CO <sub>2</sub>	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
Fuel combustion – Other	1A5	liquid	CO <sub>2</sub>										X															
Cement production	2A1		CO <sub>2</sub>	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
Glass production	2A3		CO <sub>2</sub>									X		X	X												X	
Iron and steel production	2C1		CO <sub>2</sub>	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
Enteric fermentation	3A		CH <sub>4</sub>	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
Manure management	3B		CH <sub>4</sub>								X	X	X	X	X	X	X											
Agricultural soils - direct N <sub>2</sub> O emissions from managed soils	3D1		N <sub>2</sub> O	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
Solid waste disposal	5A		CH <sub>4</sub>						X	X	X	X	X	X														

Table 1-8 indicates which source categories – including LULUCF - have been identified as key categories (LA) for every reported year from 1990 to 2014. The key categories comprise 9997.00 Gg CO<sub>2</sub>e in the year 2014, which is a share of 96.96% of Luxembourg's 2014 total GHG emissions, including LULUCF.

**Table 1-8 – Key categories (Tier 1, LA) including LULUCF based on emission data recorded in submission 2016v1**

IPCC	IPCC source category	Fuel	Gas	2014 emissions in Gg CO <sub>2</sub> e	Share in 2014 national total GHG emissions (incl. LULUCF)
1A1	Fuel combustion - Energy industries	gaseous	CO <sub>2</sub>	653.89	6.34%
1A2	Fuel combustion – Manufacturing industries and construction	gaseous	CO <sub>2</sub>	689.09	6.68%
1A3b	Fuel combustion – Transport - Road transportation	diesel oil	CO <sub>2</sub>	945.94	49.30%
1A3b	Fuel combustion – Transport - Road transportation	gasoline	CO <sub>2</sub>	5082.52	9.17%
1A4	Fuel combustion – Other sectors	gaseous	CO <sub>2</sub>	665.67	7.48%
1A4	Fuel combustion – Other sectors	liquid	CO <sub>2</sub>	770.75	6.46%
2A1	Cement production		CO <sub>2</sub>	353.79	3.43%
3A	Enteric fermentation		CH <sub>4</sub>	415.90	4.03%
4A1	Forest land remaining forest land		CO <sub>2</sub>	-419.46	4.07%
<b>all</b>	<b>Sum of all key categories</b>	<b>all</b>	<b>all</b>	<b>9997.00</b>	<b>96.96%</b>

Table 1-9 indicates which source categories have been identified as key categories (LA) incl. LULUCF for every reported year from 1990 to 2014.

**Table 1-9 – Key categories (Tier 1, LA) including LULUCF based on emission data recorded in submission 2016v1: 1990-2014**

IPCC source category	Source code	fuel	Gas	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
Fuel combustion - Energy industries	1A1	gaseous	CO <sub>2</sub>													X	X	X	X	X	X	X	X	X	X	X	X	X
Fuel combustion – Manufacturing industries and construction	1A2	liquid	CO <sub>2</sub>	X	X																			X	X			
Fuel combustion – Manufacturing industries and construction	1A2	solid	CO <sub>2</sub>	X	X	X	X	X	X	X	X													X				
Fuel combustion – Manufacturing industries and construction	1A2	gaseous	CO <sub>2</sub>	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
Fuel combustion – Transport - Road transportation	1A3b	gasoline	CO <sub>2</sub>	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
Fuel combustion – Transport - Road transportation	1A3b	diesel oil	CO <sub>2</sub>	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
Fuel combustion – Other sectors	1A4	liquid	CO <sub>2</sub>	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
Fuel combustion – Other sectors	1A4	gaseous	CO <sub>2</sub>	X	X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cement production	2A1		CO <sub>2</sub>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
Iron and steel production	2C1		CO <sub>2</sub>	X	X	X	X	X	X																			
Enteric fermentation	3A		CH <sub>4</sub>	X	X	X	X	X		X		X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
Forest land remaining forest land	4A1		CO <sub>2</sub>			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
Land converted to forest land	4A2		CO <sub>2</sub>	X																				X				

The key category with the highest contribution to the national total emissions in 2014 is *1A3b Road Transportation – diesel oil (CO<sub>2</sub>)*. The contribution to the national total emissions in the base year was 10.43%, whereas in 2014 this contribution has increased to 47.19%.<sup>25</sup> 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<sub>2</sub>)* is the most important category in terms of emission trends and, since 1990 emissions have increased by 281.05%.

The second most important source of greenhouse gas emissions in 2014 in Luxembourg is *1A3b Road Transportation – gasoline (CO<sub>2</sub>)*. Its contribution to national total emissions is 8.78% for 2014 compared to 9.93% in the base year, followed by *1A4 – Other sectors – gaseous fuels (CO<sub>2</sub>)* with a contribution of 7.16% in 2014 (2.64% in 1990).

The key category with the highest contribution to national removals is *4.A.1 Forest land remaining forest land (CO<sub>2</sub>)*. In the key category analysis including LULUCF it is the seventh largest category in the level assessment (4.07 % in 2014) and is also a key category in the trend assessment. Removals from this category increased by 731.4 % from 1990 to 2014. This sharp increase is mainly due to the fact that in 1990 this category was a source (see Section 0 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.

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<sup>25</sup> 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.**

IPCC Category	Category Name	Fuel	GHG	TA excl. LULUCF	TA incl. LULUCF
1A2	Manufacturing Industries and Construction	gaseous	CO <sub>2</sub>	X	X
1A2	Manufacturing Industries and Construction	liquid	CO <sub>2</sub>		X
1A2	Manufacturing Industries and Construction	solid	CO <sub>2</sub>	X	X
1A3b	Road Transportation	diesel oil	CO <sub>2</sub>	X	X
1A3b	Road Transportation	gasoline	CO <sub>2</sub>	X	X
1A4	Other Sectors	gaseous	CO <sub>2</sub>	X	X
1A4	Other Sectors	liquid	CO <sub>2</sub>	X	X
2A1	Cement Production		CO <sub>2</sub>	X	X
2C1	Iron & Steel Production		CO <sub>2</sub>	X	X
4A1	Forest Land remaining Forest Land		CO <sub>2</sub>	NA	X
4A2	Land Converted to Forest Land		CO <sub>2</sub>	NA	X

### 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.

The key category analysis was performed using the Tier 1 approach on the basis of submission 2016v1 to the UNFCCC. It comprises a level assessment for all years between 1990 and 2013, as well as a trend assessment for the trend of the year 2014 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.

In Luxembourg's case, in the UNFCCC inventory, only 4.A.1 - *Forest Land Remaining Forest Land* is regarded as a key category in 2014. As neither AR (afforestation and reforestation) nor D (deforestation) are corresponding Kyoto Protocol categories to IPCC category 4.A.1 (compare Table 6 in this NIR and Table 5.4.4 in GPG LULUCF), none of the mandatory Article 3.3 activities – Luxembourg opted for – are identified as key according to the quantitative analysis.

## **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<sup>26</sup> 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 Air & Noise Division 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:
  - EU GHG Monitoring Mechanism (525/2013/EC (repealing 280/2004/EC) & 2005/166/EC)
  - NEC Directive (2001/81/EC)
  - 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;

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<sup>26</sup> Grand-Ducal Regulation (Règlement grand-ducal du 1 août 2007)



- 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<sup>27</sup>.

Luxembourg's QMS follows a Plan-Do-Check-Act-Cycle (PDCA-cycle)<sup>28</sup>, which is an accepted model for pursuing a continual improvement of performance according to international standards 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:

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<sup>27</sup> SEG Umwelt-Service GmbH, Auf der Haardt 2, D – 66693 Mettlach, <http://www.seg-online.de>

<sup>28</sup> <http://www.asq.org/learn-about-quality/project-planning-tools/overview/pdsa-cycle.html>

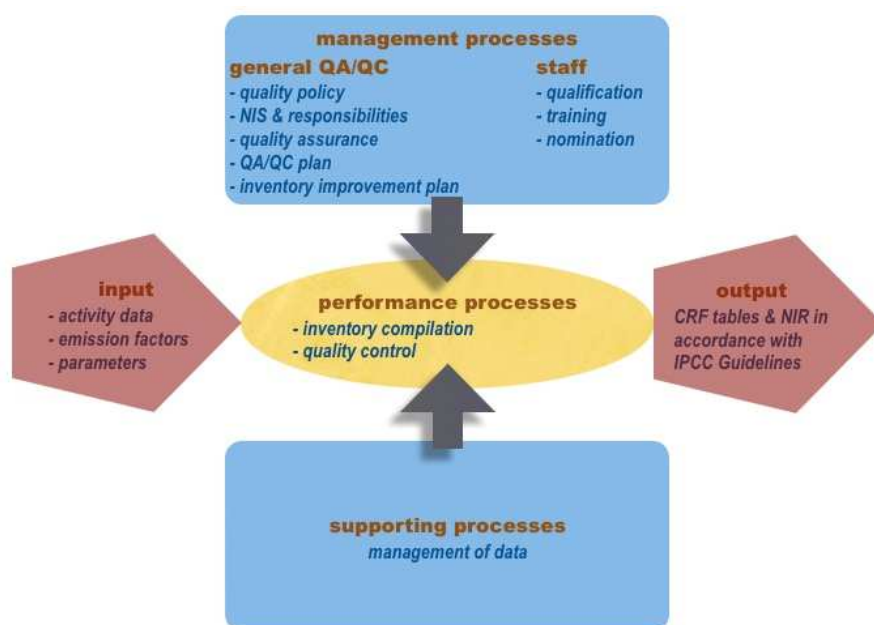
- check integrity, correctness and completeness of data;
- identify errors and omissions;
- reduce uncertainties of emission estimates;
- document and archive inventory calculation sheets and background data.

### 1.6.3 QMS Structure

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

- 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.
- 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.
- 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 to 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 IPCC 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	QA/QC 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, QA/QC 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 management	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

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

- 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.
- Checklists for data supplier that have to be completed by external suppliers of input data in order to assure the reliability of reported data.
- 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	check done			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
<b>Content check</b>																		
<i>Trend checks</i>																		
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																		
<b>Check time series consistency</b>																		
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																		
<b>Check completeness</b>																		
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																		
<b>Formal check</b>																		
Collection of data is understandable																		
<b>Check that assumptions and criteria for the selection of data are documented</b>																		
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																		
<b>Check for transcription errors in data input and reference</b>																		
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																		
<b>Check that parameters and units are correctly recorded and that appropriate conversion factors are used</b>																		
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																		
<b>Uncertainties</b>																		
<b>check done</b>																		
Greenhouse gas	CO2	CH4	N2O	Remarks	Date	Person												
<b>Content check</b>																		
<b>Check that uncertainties in emissions and removals are estimated and calculated correctly</b>																		
Check that qualifications of individuals providing expert judgement for uncertainty estimates are appropriate																		
Check that qualifications, assumptions and expert judgements are recorded																		
<b>Formal check</b>																		
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:

- 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)
  - 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)
  - 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)
  - 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:
  - 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
  - whether data acquisition, calculation, referencing and archiving is handled according to the defined methods
  - whether there are enough resources for inventory work
  - whether relevant data are available and if the reliability of external data is guaranteed
  - whether the QMS system needs improvement
  - 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"<sup>29</sup>. 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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<sup>29</sup> <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.<sup>30</sup> 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.

Since 2007, when the first study on uncertainties was undertaken, some of the CRF sectors have been revised. Specifically, the following changes have been introduced to Luxembourg's inventory:

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<sup>30</sup> 2000 IPCC GPG – Chapter UNCERTAINTIES

- a new setup of the data structure, now following the CRF categories, rather than the CORINAIR SNAP31 structure. This required the calculation algorithm to be fully overhauled;
- new key categories were identified and for those new categories uncertainties are defined for activity data and emission factors;
- important technical and scientific developments were implemented;
- a revision of the transport emissions and split into national and international use of domestic fuel sales. While this revision is currently under preparation only, it allows for a reassessment of uncertainty information;
- detailed information on F-gas emissions has been added to the national inventory;
- the inventory has been extended by data on land use, land use change and forestry (LULUCF).

For submission 2016v1, only a Tier 1 uncertainty analysis was carried out. As important methodological changes have occurred in several sectors, it is foreseen to re-assess the input uncertainties and to perform a Tier 2 analysis for the next submission.

#### **1.7.1.1 Data origin**

##### **1.7.1.1.1 Data origin - Energy & Transport**

###### **Activities**

Since 2011, the activity data are taken from energy statistics which are prepared by STATEC, (national energy balance and IEA Joint Questionnaires). A comprehensive top-down – bottom-up approach was conducted by the Environment Agency for the entire energy sector. The following partners were involved in these:

- «Ministère de l'Economie et du Commerce Extérieur», «Ministère du développement durable et de infrastructures (Environnement, Transports)» ;
- Administration de l'Environnement: Division Air/Bruit, Division des Déchets, Division des Établissements Classés, Registre national des quotas d'émission de gaz à effet de serre du Luxembourg ;
- Administration des Douanes et Accises (Ministère des Finances);
- Service Central de la Statistique et des Etudes Economiques (STATEC);
- all relevant fuel importers and fuel distributors;
- plant operators;
- Société Nationale des Chemins de fer Luxembourgeois (CFL).

Primary energy carrier in Luxembourg is natural gas. Gas is used in the major power plant (TwinErg), in industry including electro-steel works (ArcelorMittal) and in domestic heating (private households as well as commerce). The Ministry of Economic Affairs collects consumption / import data from the only provider CREOS. Since 2006, other providers also entered the market, but they still use the transport facilities (pipelines) of CREOS – thus the data situation remains stable.

Comparison of data is possible between figures reported by industry participating to the ETS, and the distributor's figures as well as emission reports of plant operators. This is the only country-specific information on uncertainty that is available.

The amount of gasoline and diesel fuel being sold in Luxembourg's petrol stations is monitored by monthly reports from the petrol distributors. Eight major companies exist; products are being refined mostly in Belgium and Netherlands and imported. Even strategic reserves (90 days consumption) are being stored outside Luxembourg. It is believed that the information provided is of high quality.

Liquid fuels play also a role in the commerce and private combustion sector, even if this contributes much less to overall emissions. However, distribution of heating fuels outside Luxembourg may be prone to foreign legislation and taxation thus limiting importance of exports.

Solid fuels played a considerable role in the past, both in the power plant and in the steel industry sectors. This changed during the mid 1990's, when the blast furnaces were closed down and the modern gas fired power plant was started up. An analysis of solid fuel combustion and its quality is somewhat difficult to perform as an ex post analysis.

#### Emission factors (1 A Stationary fuel combustion)

Emission factors for CO<sub>2</sub> are generally straightforward; they derive from the carbon content of the fuel. As the carbon content of fuels is closely coupled to the energy content, and the assessment of energy quantities is normally given as energy units (or in other units together with a defined conversion factor), thus much of the uncertainty included in the numbers presented is present likewise in the conversion factor and cancels out.

The situation for CH<sub>4</sub> and N<sub>2</sub>O emission factors is quite different. Factors have been taken from IPCC 2006 guidelines (default factors).

#### Emission factors (1 A 3 Mobile fuel combustion)

With regard to CO<sub>2</sub>, Luxembourg's emissions of “fuel sold” are well covered by the fuel import statistics. CH<sub>4</sub> and N<sub>2</sub>O emissions factors for road transportation, the uncertainties result from expert judgment<sup>32</sup>.

#### 1.7.1.1.2 Data origin - Industrial Processes

Within processes, two key sources are to be noted (cement production, iron and steel production). In addition, a quite limited number of industrial installations had to be considered. Product use is covered in a specific study on F-gases.

##### Cement production:

One plant exists in Luxembourg, which exclusively produces clinker. Any confusion with total cement production is impossible, as cement is mixed (from the clinker produced) at a different facility of the same company. Ca content of product is used to estimate CO<sub>2</sub> emissions (according to IPCC methodology) which are a stoichiometric factor. Errors could only occur at high Mg content which however is not the case. Ca content as well as amount of production was submitted directly by the producer. Ca content is fairly stable near 67%, there is little reason for uncertainty. Using IPCC default uncertainty estimates (IPCC, 2006) thus provides most probably an overestimation. Using an activity uncertainty of 1.5%, emission factor uncertainty of 2% not including 1.5% analytical uncertainty for Ca content (including this factor makes 2.5% for emission factor uncertainty) yields an overall uncertainty of 3%.

##### Iron and Steel production:

Very different conditions exist for the situation of 1990 and since about 2000. Originally, Luxembourg steel industry used basic oxygen furnaces that were fed with one third scrap metal, and two thirds raw iron from blast furnaces. Blast furnaces operated on imported coke, anthracite and calcium oxide. Thus emissions due to coking or calcination never occurred in Luxembourg. In the 1990's, basic oxygen furnaces were replaced by electric arc furnaces to be operated on scrap only. Blast furnaces became redundant by the end of 1997.

Both parts of steel production combine process and energy related emissions in a way that make them difficult to be disentangled. For pragmatic reasons (and to be as close as reasonable to the real situation) gaseous fuels have been considered causing energy related emissions (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. The most problematic point here is probably the differentiation between blast furnace gas and the underlying solid fuels. This definitely is correlated via the energy balance.

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<sup>32</sup> Komobile, FVT: Aktualisierung der Zeitreihen zum Kraftstoffexport und der Emissionen von klimarelevanten Gasen und Luftschadstoffen des Verkehrssektors in Luxemburg von 1990 – 2012, Endbericht, 2014, Graz, Luxemburg

Three Steel plants exist in Luxembourg, all of the same company (ArcelorMittal). In addition, a plant recuperating iron from slag and collected dust (direct reduction furnace) is also considered (Primorec), although the PRIMUS process was shut down in 2009. Information on production, carbon content and amount of fuels is available in all cases. In the electric arc furnaces, a considerable fraction of carbon (10-15%) contributing to CO<sub>2</sub> derives from electrodes.

#### Glass production:

One facility produces glass and provides production figures. The emission factor derives from the loss on ignition of raw materials, also provided by the manufacturer. This factor is confirmed by an alternative method assessed according to the ETS system. Still the uncertainty estimates have been adapted from the IPCC default (IPCC, 2006) in a national approach and in consequence the 2% used for activity and 5% for emission factor more probably are a high estimate of this sector's uncertainty.

#### F-gases:

Significant contributions to total emissions derive from “mobile air conditioning”, from “stationary installations”, and from soundproof windows. For the base year 1995 (different to that of the other greenhouse gases), emissions from cartridges of PU-foam were significant also. In general, estimates are highly uncertain – especially as it is almost impossible to assess cross-border effects. *E.g.* repair (refilling) of refrigeration systems can be done by national or foreign technicians – interviewing support suppliers in Luxembourg alone will not work. New information might become available through the monitoring provisions of the European F-Gas Regulation<sup>33</sup>.

#### 1.7.1.1.3 Data origin - Solvent and Other product use

##### Solvents:

A study assessing emissions from solvent use has been completed in 2008. The main activity data are the foreign trade statistics and production statistics as well as inquiries from relevant plant operators.

##### N<sub>2</sub>O use:

Based on figures in the German inventory, a per-capita rate of 40g/person and year have been applied. No information on uncertainty is presented.

#### 1.7.1.1.4 Data origin - Agriculture

Assessment of CH<sub>4</sub> emissions from Luxembourg's agriculture follows strictly IPCC guidelines. Since 2007, a common base of statistics exists between the statistical office STATEC and the Service d'Economie Rurale (Ministry of agriculture) (unpublished data) for data on the structure of

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<sup>33</sup> Regulation (EC) No 842/2006 of the European Parliament and of the Council of 17 May 2006 on certain fluorinated greenhouse gases

agricultural holdings. Previously, differences less than 1% e.g. on extension of agricultural land (130,000 ha) were observed. Production data produced by the Service d'Economie Rurale are estimated to be similarly precise.

Since the BSE crises, a register is used to cover each individual bovine animal. Ear marks had been used before already. The register categories (using the Belgian system SANITEL, where Luxembourg is treated like a Belgian province) do not always provide the full information required for emission calculation – specifically, no differentiation between milk cow and suckler cow is directly available through the register. However it is possible to approach these categories through the characteristics contained in the register and other information available. Luxembourg national figures on milk yield have been applied.

The agricultural sector, especially bovine production, is extremely carefully being supervised – for sanitary reasons, but also because of subsidies. The uncertainty is somewhat higher in pigs than bovines (numbers in reports by farms are rounded) or in sheep, which are often reported by part-time farmers; in contrast, goat numbers are more precise as they derive from larger farms. Horses are only covered if “horse clubs” are registered as farms– pleasure horses are not included in the statistics.

Differentiation between systems (solid-liquid) is based on expert judgement (ASTA). Bovines are assumed to spend half a year (6 months) outside, and 6 months inside buildings.

Bookkeeping regarding nitrogen balance is provided by about 800 farms (this covers more than half of the full-time farmers), and total nitrogen balances are derived from this number according to the agricultural area (not according to crop). Fertilizer sales statistics are not being used, as there is considerable “private level” fertilizer sales across the border – not covered by export statistics.

Precise data are available since 1999. Improved application has been shown to positively influence N-balances, but fertilizer prices are also reflected in the statistical data.

N from manure is not considered in N balances, but instead is derived from the animal numbers.

N-fixing crops are taken from crop statistics (alfalfa, clover – problem are mixtures with grassland as extent of mixture is not clear); for sewage sludge see chapter on Wastewater.

#### 1.7.1.1.5 Data origin - LULUCF Error! Bookmark not defined.

The sector land use, land use change and forestry (LULUCF) has been completely revised in Luxembourg's inventory since the uncertainty study in 2007. A detailed analysis of Luxembourg's LULUCF sector uncertainty was based on assessing uncertainty of these major parameters:

Wood harvest:

Part of national forests is public property (state forest and community forests) where foresters provide data to statistics in a “common” but unknown quality. The somewhat larger part of forests (52%), however, is private – there are only very few major landowners, the majority is owned and operated by many very small holders, often not anymore connected to agriculture. Little is known on wood amounts harvested. Some information indicates that the typical spruce forests are clear-cut after 50 years, but no statistical confirmation exists that would substantiate such a practice. For this reason, in the inventory, private forest was treated just as public forest. This extrapolation definitely establishes the overall uncertainty of wood harvest, any accounting uncertainty may be considered negligible.

#### Woody biomass growth in forests:

Currently, assessments have to be based on one forest inventory, the second forest inventory of Luxembourg is currently under preparation. Biomass growth therefore needs to be estimated from an analysis of the existing inventory (trunk diameters, densities, ...) and biomass increases are estimated from growth factors by age category and tree species. Results are available both for private and public forests.

#### Area of land use:

Satellite and aerial photography has been used, assessments have been repeated already to also allow to establish the extent of changes. LUXSPACE, in their report on land use attribution claim, accuracy in identification of certain land use / land cover types (OBS nomenclature) near 90%, *i.e.* in 90% of all cases assignment is correct. What seems to be a high number actually turns out not to be too helpful for overall uncertainty assessment of LULUCF emissions. After all, it is important to understand if, in terms of C uptake/emission, the misallocation refers to classes of identical or very different C pools, *i.e.* whether a misallocation actually affects the C balance. Moreover, no information is provided on “false positives”, *i.e.* misallocation of an area of land to a certain land type in question.

#### Wood growth of the first age class:

The first age class (after clear cut or land use change) would not be assessed differently to wood growth generally. Uncertainties up to 25% are possible here, due to overestimation of number of seedlings, or underestimation of trunk diameters. The common practice of planting broadleaf forest (oaks and beeches) in public forest, while growing coniferous trees (Douglas firs) in private forests is reflected in the growth factors used.

#### Woody biomass stock:

Only in exceptional cases land use change happens –e.g. in certain construction projects, when at the same time also compensation areas have to be converted to forests. In general, woody biomass removal other than harvests may be safely ignored.

#### 1.7.1.1.6 Data origin - Waste

##### Waste disposal:

Waste disposal is organized via three regional disposal districts, which originally have been formed due to hygienic considerations. The southern district (SIDOR) operates a waste incinerator (MWI), which is considered in the “energy” section. About two thirds of Luxembourg’s waste are being combusted, approx. 130000 t/yr. Recently, the northern district (SIDEDEC) started a mechanical-biological treatment plant. Routinely separation of combustible material has been performed, which is used at the only waste incinerator. The remaining waste is landfilled, like also in the eastern district (SIGRE) where only simple (cold) pre-treatment is performed. Recovery of landfill waste started in 2002 (flaring) and 2000 (electricity and heat plant), respectively.

Amounts of waste originally have been estimated by volume only, but since the 1990’s weight of waste is available. Waste fractions have been analysed in specific campaigns (mid-1990’s, mid-2000’s, and around 2000 for SIDOR only), specifically clustering information by consumer habits and availability of waste separation facilities.

Waste analysis is being used to determine IPCC waste fractions to which default DOC contents are applied. Evaluation of results of waste analysis (in other context) is being performed on differences between years smaller than 1 abs.-%, indicating that the authors put large confidence in the results. No information is available on the composition of the combustible fraction taken off the SIDEDEC waste and delivered to the MWI. This fraction will have a higher C content than the average waste, neglecting may lead to a potential underestimation of the fossil CO<sub>2</sub> emitted from the MWI and a potential overestimation of total DOC amounts in SIDEDEC.

In accordance with IPCC guidelines, conversion of DOC into 50% methane is assumed using a first order decay function, not accounting for methane oxidation in the top soil layer. Recovered CH<sub>4</sub>, as determined from monthly reports of the landfill operators (measured quantities) is subtracted from the estimated emissions.

##### Composting:

Seven composting installations exist in LU, plus one that co-composts sewage sludge. The latter (“soil concepts” plant) uses active ventilation and operates fully aerobic – without methane formation. The other plants operate in part under anaerobic conditions, with a residence time in the composter of a few weeks. Emission calculation is performed using default factors from the IPCC guidelines, where also uncertainty estimates can be taken from.



### Wastewater:

The division of water protection in the Ministry of interior and of the greater region performs emission calculation themselves. The sector is not among the key sources. Measured data of organic C and organic N are being used to understand the flows of C and N in the systems. This allows circumventing the less meaningful parameters of population equivalents. In Luxembourg, there are 7 waste water treatment plants designed for a population equivalent of >50000, 8 additional > 10000, plus 32 > 2000. These plants provide analytical data of input and output N and C, thus also allowing estimating the conversion. 96% of total wastewater from Luxembourg is covered.

#### **1.7.1.2 Assessing input uncertainties**

This section will be reworked and the text will be integrated in the paragraphs related to uncertainty in the respective sector chapters of the NIR.

In the following the assessing input uncertainties as evaluated within the framework of the study **Error! Bookmark not defined.** are described.

##### **1.7.1.2.1**      Method

Information on uncertainty from a number of national assessments<sup>34</sup> is used and adapts the factors presented with the information of experts on the Luxembourg situation. The basic idea was to evaluate uncertainties at the same level as input data are available.

In many cases this was not feasible. Input data for emission inventories are often available only or at least at better quality at an aggregated level than at the most detailed level. Here we employed uncertainties at the level where the best quality was expected (coupling of inputs). This approach helped avoiding the introduction of unnecessary (calculation-related) additional uncertainties. As will be explained in the respective calculation algorithms, only the Monte-Carlo approach is able to appropriately handle this situation.

##### **1.7.1.2.2**      Energy sector

Following the information of the national experts, energy activity data were understood to be best available at the level of national total for gas, liquid fuels and solid fuels, respectively. The national trade balances allowed to account for the total, the differentiation into individual sectors was considered less reliable. This situation is rather typical for national energy balances (see *e.g.* Austria<sup>35</sup>). Consequently, uncertainty estimates for activities in the energy sector were given

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<sup>34</sup> Charles et al., 1998, AEAT-2688-1, AEA Technology, Culham (UK) ; Monni and Syri, 2003, VTT Research Notes 2209, Espoo (Finland) ; Ramirez-Ramirez et al., 2006, NWS-E-2006-58, Copernicus Institute for Sustainable Development and Innovation, Utrecht (Netherlands) ; Winiwarter, 2008, ARC-sys-0154, Vienna (Austria).

<sup>35</sup> Winiwarter, 2008, ARC-sys-0154, Vienna (Austria).

separately for gaseous, liquid and solid fuels, normally without further subdivision. Activities within each of the groupings were considered fully “correlated”, *i.e.* statistically dependent. Due to the detailed assessment and the fact that just a single provider is responsible for all imports, we assume an uncertainty range of +/- 0.5%. Liquid fuels are regarded as uncertain by +/- 2% in 1990, in recent times (due to improved data quality schemes established with the requirement of maintaining a strategic reserve) +/- 1%. More complex is the situation for solid fuels, where we separately treat coal (2% uncertainty, just as liquids), coke (3% uncertainty, following Monni and Syri<sup>34</sup>, for steel industry: the difference being that data derive from private industry which is less easily controllable, especially with regard to the old data of the 1990's) and electric furnace electrodes (5% uncertainty, as not included in the energy balance). The relevant uncertainty of steel industry activity, other than electrodes, is considered to be covered in the uncertainty of coke – which also includes gaseous fuels (coke oven gas) derived from solids. Uncertainty of fuels from biomass is estimated at 10%.

Also emission factors of fuel combustion are considered strongly related. For fossil fuels, CO<sub>2</sub> emission factors directly derive from the carbon content, which is very well understood for gaseous and liquid fuels (0.5% uncertainty, respectively; as CO<sub>2</sub> emissions from transport are being calculated according to fuel sold, this factor is directly applicable also on “road fuel sales to non residents” or “road fuel exports”: see Section 2.1.6). Carbon content of solid fuels is a function of fuel quality, which not always is perfectly understood – especially concerning the old data of the 1990's. We apply an uncertainty of 3% (following Monni and Syri<sup>34</sup>, for generic solid fuel emission factors) for all solid fuels, and 1% for the situation now which is more strongly controlled by coal use in boilers than previously. High quality electrodes are regarded to be covered by the 1% uncertainty of emission factor over the whole period.

For biomass and waste, the uncertainty is relatively high as depending on the fossil carbon component in waste (biomass carbon is considered neutral), we use 20% following Charles *et al.* <sup>34</sup>.

Even if a number of different emission factors on CH<sub>4</sub> and N<sub>2</sub>O are available, these factors often refer to very few measurements and a subsequent source specific interpretation. Thus it seems useful to also consider these uncertainty estimates to be correlated. While we use uncertainty estimates for solid, liquid and gaseous fuels as well as biomass&waste all at +/- 50% (Charles *et al.* <sup>34</sup>), we consider at least those four groups statistically independent, both in the case of N<sub>2</sub>O and CH<sub>4</sub>. In contrast to CO<sub>2</sub>, here we regard the emission factor of coke oven gas to be related to that of gaseous fuels, instead of to solid fuels.

Separate treatment was only required for transport emissions. CH<sub>4</sub> and N<sub>2</sub>O emissions factors for road transportation, uncertainties of 20% are assumed according to expert judgment<sup>36</sup>.

#### 1.7.1.2.3 Industry and product use<sup>Error! Bookmark not defined.</sup>

Iron and steel industry (as described above) is being dealt with according to the energy sector (solid fuels), with the sole exception of electrodes (5% uncertainty of activity). As the routes of steel production are entirely different in 1990 and 2006, also the associated uncertainties are different and are considered statistically independent.

Energy related emissions from cement and glass production are also covered in energy, including waste combustion. For the decarbonising part of the processes we refer to the uncertainty reported for Luxembourg directly, which is 1.5% for activity and 2.5% for the CO<sub>2</sub> emission factor. Likewise we apply national factors also to the glass industry (2% for activity, 5% for emission factor).

For F-gas emissions, the default uncertainty values from the 2006 IPCC Guidelines were applied. A detailed assessment of input uncertainties will be carried out for the next submission.

#### 1.7.1.2.4 Solvents and Other Product Use

Assessing emissions from solvent follows the Austrian approach (Windsperger, pers. information). Thus, we also apply the Austrian uncertainty estimates (5% activity uncertainty, 10% CO<sub>2</sub> emission factor uncertainty). For N<sub>2</sub>O use we consider activity (population numbers) as exact, while the emission factor is regarded at 20% uncertainty following Monni and Syri<sup>34</sup>. This is much higher than the 1% used but not explained by Ramirez-Ramirez *et al.*<sup>34</sup> but in line with Boogerts and Starcks<sup>37</sup> who apply 25%.

#### 1.7.1.2.5 Agriculture

For uncertainties from the agriculture sector, please refer to the corresponding sections in Chapter 5.

#### 1.7.1.2.6 LULUCF<sup>Error! Bookmark not defined.</sup>

The uncertainty of emissions from the LULUCF sector has been calculated separately according to a Tier 1 approach. This uncertainty is estimated at 42.3%. As important methodological changes have occurred in this sector, a detailed uncertainty assessment will be carried out for the next submission.

#### 1.7.1.2.7 Waste

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<sup>36</sup> Komobile, FVT: Aktualisierung der Zeitreihen zum Kraftstoffexport und der Emissionen von klimarelevanten Gasen und Luftschadstoffen des Verkehrssektors in Luxemburg von 1990 – 2012, Endbericht, 2014, Graz, Luxemburg

<sup>37</sup> Boogaerts and Starcks, 2004, Report 40003117, De Norske Veritas, Consulting Benelux, Antwerp (Belgium)

The high quality of information available on landfills resembles the situation of Austria. Thus based on Austrian data, uncertainty of waste deposited is considered uncertain by 12%, and the CH<sub>4</sub> emission factor by 25%. Also other uncertainty factors are copied from the Austrian inventory, but with hardly any effect on the result. Also for the sector of Land use, land use change and forestry, Austrian data have been applied. Again, this sector is extremely small in Luxembourg, such that the overall result will not be affected by any choice of parameters taken.

### **1.7.1.3 Results using the Tier 1 (error propagation) approach**

The results of the error propagation approach are presented in Table 1-11 and Table 1-12. In Luxembourg's previous Tier 1 uncertainty analyses, only key categories were included, while the uncertainty assessment presented here covers all IPCC categories. As a part of the spreadsheet development, algorithms have been established to assess the respective contributions of sources to the uncertainty of the emission level as well as to the trend uncertainty. The respective contributions of individual source sectors become explicit in columns "H" and "M" of the table (numbers printed in boldface). 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 excluding LULUCF suggests an overall level uncertainty of 2.03% and a trend uncertainty of 1.24% (Table 1-11), and the TIER 1 approach including LULUCF suggests an overall level uncertainty of 2.72% and a trend uncertainty of 1.30% (Table 1-12).

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<sub>2</sub> emission factors are much better understood (can be derived from material balances) than emission factors of CH<sub>4</sub> or N<sub>2</sub>O. The fact that, in the total inventory, N<sub>2</sub>O and CH<sub>4</sub> are less pronounced at the same time leads to a structurally lower uncertainty.

The following drivers for the level uncertainty and the trend uncertainty can be extracted from these results:

- Small contributions are basically negligible for the overall total, and most of the influence to the total derives from the very few elevated numbers.
  - Uncertainties of the emissions of the target year are being calculated in column H. Following the principles of error propagation, only the large values presented in column H for a certain source sector will provide sufficient weight to impact to the total.
  - The large contributors identified here are N<sub>2</sub>O from soil (direct emissions – 3D1 – as well as the indirect emissions – 3D2). Also the most important single sector, Diesel

fuel in road transportation, sector 1A3b, shows up – but most of all the LULUCFsector.

- Furthermore the emission table demonstrates the drastic economic changes that happened to Luxembourg over the last 20 years.
  - While emissions in 1990 largely derived from solid fuels (as used in steel industry) and in sector 2C1, iron and steel industry (as feedstock), the case of 2014 demonstrates high emissions from gas combustion. Emissions related to Diesel sales have been rising to almost half of the national total emissions while gasoline based emissions have changed only little.
  - Additionally with respect to the specific situation in Luxembourg the uncertainty associated with a previous economic situation, with steel industry a major aspect of the economy (1990), is considerably higher than today.
- Also for LULUCF from forest land (sector 4A) the situation changed completely: from being a source in 1990, the sector turned into a sink 2014.

The differences in years outlined above will not only lead to different uncertainties for base year and target year (actually, the template of the Tier 1 methodology does not evaluate the base year uncertainty), but also effect trend uncertainties. With large trends, also the uncertainties caused by the trends will tend to increase. Here is to mention the steel industry, but also consumption of liquid fuels for transport (including the associated CH<sub>4</sub> and N<sub>2</sub>O emissions) which became more important recently, even if the actual point of release is outside Luxembourg's territory.

#### **1.7.1.4 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<sup>Error! Bookmark not defined.</sup> 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. However, the input uncertainties used for the Tier 2 uncertainty analysis have not been updated since this study. Since important methodological changes have occurred in several sectors, it is foreseen to repeat a Tier 2 uncertainty analysis for the next submission, after a detailed re-assessment of all input uncertainties.

#### **1.7.1.5 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<sub>2</sub>O from soils and the uptake/release of CO<sub>2</sub> 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<sub>2</sub>O emission factors. Such validation exercises might provide a closure of the error margins.

Table 1-11 – Results of the Tier 1 uncertainty analysis excluding LULUCF.

A	B	C	D	E	F	G	H	I	J	K	L	M
Key IPCC Source Categories	Gas	1990 (BY) emissions (1995 for F-gases)  Gg CO <sub>2</sub> equivalent	2014 emissions	AD uncertainty	EF uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in 2014	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
				%	%	%	%	%	%	%	%	%
1A Stationary Combustion - Gaseous Fuels	CO <sub>2</sub>	1039.13	2113.72	0.50%	0.50%	0.71%	0.14%	9.65%	16.40%	0.05%	0.12%	0.13%
1A Stationary Combustion - Gaseous Fuels	CH <sub>4</sub>	1.04	2.29	0.50%	50.00%	50.00%	0.01%	0.01%	0.02%	0.01%	0.00%	0.01%
1A Stationary Combustion - Gaseous Fuels	N <sub>2</sub> O	0.54	1.11	0.50%	50.00%	50.00%	0.01%	0.01%	0.01%	0.00%	0.00%	0.00%
1A Stationary Combustion - Liquid Fuels	CO <sub>2</sub>	1274.48	822.24	2.00%	0.50%	2.06%	0.16%	1.88%	6.38%	0.01%	0.18%	0.18%
1A Stationary Combustion - Liquid Fuels	CH <sub>4</sub>	3.48	2.19	2.00%	50.00%	50.04%	0.01%	0.01%	0.02%	0.00%	0.00%	0.00%
1A Stationary Combustion - Liquid Fuels	N <sub>2</sub> O	14.85	10.44	2.00%	50.00%	50.04%	0.05%	0.02%	0.08%	0.01%	0.00%	0.01%
1A Stationary Combustion - Other Fuels	CO <sub>2</sub>	33.29	114.10	7.00%	20.00%	21.19%	0.22%	0.67%	0.89%	0.13%	0.09%	0.16%
1A Stationary Combustion - Other Fuels	CH <sub>4</sub>	0.25	0.94	7.00%	50.00%	50.49%	0.00%	0.01%	0.01%	0.00%	0.00%	0.00%

A	B	C	D	E	F	G	H	I	J	K	L	M
Key IPCC Source Categories	Gas	1990 (BY) emissions (1995 for F-gases)	2014 emissions	AD uncertainty	EF uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in 2014	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Gg CO <sub>2</sub> equivalent		%	%	%	%	%	%	%	%	%
1A Stationary Combustion - Other Fuels	N <sub>2</sub> O	0.40	1.50	7.00%	50.00%	50.49%	0.01%	0.01%	0.01%	0.00%	0.00%	0.00%
1A Stationary Combustion - Biomass	CH <sub>4</sub>	5.50	8.34	10.00%	50.00%	50.99%	0.04%	0.03%	0.06%	0.01%	0.01%	0.02%
1A Stationary Combustion - Biomass	N <sub>2</sub> O	1.81	3.56	10.00%	50.00%	50.99%	0.02%	0.02%	0.03%	0.01%	0.00%	0.01%
1A Stationary Combustion - Solid Fuels	CO <sub>2</sub>	5317.44	185.90	3.00%	3.00%	4.24%	0.07%	32.90%	1.44%	0.99%	0.06%	0.99%
1A Stationary Combustion - Solid Fuels	CH <sub>4</sub>	5.40	0.64	3.00%	50.00%	50.09%	0.00%	0.03%	0.00%	0.02%	0.00%	0.02%
1A Stationary Combustion - Solid Fuels	N <sub>2</sub> O	5.94	0.88	3.00%	50.00%	50.09%	0.00%	0.03%	0.01%	0.02%	0.00%	0.02%
1A3a Transport - Civil Aviation	CO <sub>2</sub>	0.21	0.50	2.00%	0.50%	2.06%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1A3a Transport - Civil Aviation	CH <sub>4</sub>	0.00	0.00	2.00%	100.00%	100.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1A3a Transport - Civil Aviation	N <sub>2</sub> O	0.00	0.00	2.00%	150.00%	150.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%



A	B	C	D	E	F	G	H	I	J	K	L	M
Key IPCC Source Categories	Gas	1990 (BY) emissions (1995 for F-gases)  Gg CO2 equivalent	2014 emissions	AD uncertainty	EF uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in 2014	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
				%	%	%	%	%	%	%	%	%
1A3b - Road Transportation - Diesel Oil	CO2	1342.84	5082.52	1.00%	0.50%	1.12%	0.53%	30.70%	39.44%	0.15%	0.56%	0.58%
1A3b - Road Transportation - Diesel Oil	CH4	0.48	0.27	1.00%	20.00%	20.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1A3b - Road Transportation - Diesel Oil	N2O	2.65	46.07	1.00%	20.00%	20.02%	0.09%	0.34%	0.36%	0.07%	0.01%	0.07%
1A3b - Road Transportation - Gasoline	CO2	1277.48	945.94	1.00%	0.50%	1.12%	0.10%	0.94%	7.34%	0.00%	0.10%	0.10%
1A3b - Road Transportation - Gasoline	CH4	10.93	1.85	1.00%	20.00%	20.02%	0.00%	0.06%	0.01%	0.01%	0.00%	0.01%
1A3b - Road Transportation - Gasoline	N2O	13.21	2.98	1.00%	20.00%	20.02%	0.01%	0.06%	0.02%	0.01%	0.00%	0.01%
1A3b - Road Transportation - LPG	CO2	11.34	4.03	10.00%	20.00%	22.36%	0.01%	0.04%	0.03%	0.01%	0.00%	0.01%
1A3b - Road Transportation - LPG	CH4	0.09	0.01	10.00%	50.00%	50.99%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1A3b - Road Transportation -	N2O	0.13	0.01	10.00%	50.00%	50.99%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

A	B	C	D	E	F	G	H	I	J	K	L	M
Key IPCC Source Categories	Gas	1990 (BY) emissions (1995 for F-gases)  Gg CO <sub>2</sub> equivalent	2014 emissions	AD uncertainty	EF uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in 2014	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
				%	%	%	%	%	%	%	%	%
LPG												
1A3c - Railways	CO <sub>2</sub>	24.72	10.13	2.00%	0.50%	2.06%	0.00%	0.08%	0.08%	0.00%	0.00%	0.00%
1A3c - Railways	CH <sub>4</sub>	0.03	0.01	2.00%	50.00%	50.04%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1A3c - Railways	N <sub>2</sub> O	2.85	1.17	2.00%	140.00%	140.01%	0.02%	0.01%	0.01%	0.01%	0.00%	0.01%
1A3d - Navigation	CO <sub>2</sub>	0.97	1.07	2.00%	0.50%	2.06%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%
1A3d - Navigation	CH <sub>4</sub>	0.00	0.00	2.00%	50.00%	50.04%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1A3d - Navigation	N <sub>2</sub> O	0.01	0.01	2.00%	140.00%	140.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1A3d - Navigation	CO <sub>2</sub>	0.30	0.14	1.00%	0.50%	1.12%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1A3d - Navigation	CH <sub>4</sub>	0.01	0.00	1.00%	50.00%	50.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1A3d - Navigation	N <sub>2</sub> O	0.00	0.00	1.00%	140.00%	140.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1B2b - Fugitive Emission from Natural Gas	CO <sub>2</sub>	0.03	0.05	1.00%	0.50%	1.12%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

A	B	C	D	E	F	G	H	I	J	K	L	M
Key IPCC Source Categories	Gas	1990 (BY) emissions (1995 for F-gases)	2014 emissions	AD uncertainty	EF uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in 2014	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Gg CO <sub>2</sub> equivalent		%	%	%	%	%	%	%	%	%
1B2b - Fugitive Emission from Natural Gas	CH <sub>4</sub>	19.36	38.42	1.00%	40.00%	40.01%	0.14%	0.17%	0.30%	0.07%	0.00%	0.07%
2A1 - Cement Production	CO <sub>2</sub>	569.88	353.79	1.50%	2.50%	2.92%	0.10%	0.95%	2.75%	0.02%	0.06%	0.06%
2A3 - Glass Production	CO <sub>2</sub>	53.57	61.07	1.50%	5.00%	5.22%	0.03%	0.13%	0.47%	0.01%	0.01%	0.01%
2C1 - Iron & Steel Production	CO <sub>2</sub>	984.91	102.46	3.00%	1.00%	3.16%	0.03%	5.59%	0.80%	0.06%	0.03%	0.07%
2D1 - Lubricant use	CO <sub>2</sub>	6.20	4.37	5.00%	50.00%	50.25%	0.02%	0.01%	0.03%	0.00%	0.00%	0.00%
2D2 Paraffin wax use	CO <sub>2</sub>	0.21	1.70	5.00%	100.00%	100.12%	0.02%	0.01%	0.01%	0.01%	0.00%	0.01%
2D3 - solvent use	CO <sub>2</sub>	23.90	10.96	50.00%	50.00%	70.71%	0.07%	0.07%	0.09%	0.03%	0.06%	0.07%
2D3 - urea-based catalysts	CO <sub>2</sub>	0.00	9.42	20.00%	5.00%	20.62%	0.02%	0.07%	0.07%	0.00%	0.02%	0.02%
2F - Product Uses as Substitutes for ODS	F-gases	17.90	64.37	30.00%	20.00%	36.06%	0.22%	0.38%	0.50%	0.08%	0.21%	0.23%
2G - Other Product Manufacture and Use	F-gases	1.39	10.11	30.00%	20.00%	36.06%	0.03%	0.07%	0.08%	0.01%	0.03%	0.04%

A	B	C	D	E	F	G	H	I	J	K	L	M
Key IPCC Source Categories	Gas	1990 (BY) emissions (1995 for F-gases)	2014 emissions	AD uncertainty	EF uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in 2014	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Gg CO <sub>2</sub> equivalent		%	%	%	%	%	%	%	%	%
2G - Other Product Manufacture and Use	N <sub>2</sub> O	7.28	27.48	20.00%	20.00%	28.28%	0.07%	0.17%	0.21%	0.03%	0.06%	0.07%
3A1 - Enteric Ferm. - Cattle	CH <sub>4</sub>	428.44	407.70	2.00%	20.00%	20.10%	0.76%	0.39%	3.16%	0.08%	0.09%	0.12%
3A2 - Enteric Ferm. - Sheep	CH <sub>4</sub>	1.78	2.13	10.00%	30.00%	31.62%	0.01%	0.01%	0.02%	0.00%	0.00%	0.00%
3A3 - Enteric Ferm. - Swine	CH <sub>4</sub>	2.83	3.27	5.00%	30.00%	30.41%	0.01%	0.01%	0.03%	0.00%	0.00%	0.00%
3A4 - Enteric Ferm. - Other livestock	CH <sub>4</sub>	0.98	2.80	10.00%	30.00%	31.62%	0.01%	0.02%	0.02%	0.00%	0.00%	0.01%
3B1.1 - Manure Man. - Cattle	CH <sub>4</sub>	40.93	49.23	2.00%	70.00%	70.03%	0.32%	0.12%	0.38%	0.08%	0.01%	0.08%
3B1.2 - Manure Man. - Sheep	CH <sub>4</sub>	0.04	0.05	10.00%	70.00%	70.71%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
3B1.3 - Manure Man. - Swine	CH <sub>4</sub>	10.87	11.39	5.00%	70.00%	70.18%	0.07%	0.02%	0.09%	0.01%	0.01%	0.01%
3B1.4 - Manure Man. - Other livestock	CH <sub>4</sub>	0.13	0.31	10.00%	70.00%	70.71%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
3B2 - Manure Management	N <sub>2</sub> O	39.08	34.76	15.00%	100.00%	101.12%	0.33%	0.02%	0.27%	0.02%	0.06%	0.06%

A	B	C	D	E	F	G	H	I	J	K	L	M
Key IPCC Source Categories	Gas	1990 (BY) emissions (1995 for F-gases)  Gg CO <sub>2</sub> equivalent	2014 emissions	AD uncertainty	EF uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in 2014	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
				%	%	%	%	%	%	%	%	%
3D1 - Agric. Soils - direct N <sub>2</sub> O emissions from managed soils	N <sub>2</sub> O	139.48	113.00	10.00%	150.00%	150.33%	1.58%	0.03%	0.88%	0.04%	0.12%	0.13%
3D2 - Agric. Soils - indirect N <sub>2</sub> O emissions from managed soils	N <sub>2</sub> O	50.06	41.49	10.00%	150.00%	150.33%	0.58%	0.00%	0.32%	0.00%	0.05%	0.05%
3G - Liming	N <sub>2</sub> O	0.59	5.81	20.00%	150.00%	151.33%	0.08%	0.04%	0.05%	0.06%	0.01%	0.06%
5A - Solid Waste disposal on Land	CH <sub>4</sub>	79.92	28.87	12.00%	25.00%	27.73%	0.07%	0.29%	0.22%	0.07%	0.04%	0.08%
5B - Wastewater handling	CH <sub>4</sub>	0.00	5.57	10.00%	50.00%	50.99%	0.03%	0.04%	0.04%	0.02%	0.01%	0.02%
5B - Wastewater handling	N <sub>2</sub> O	0.00	3.98	10.00%	50.00%	50.99%	0.02%	0.03%	0.03%	0.02%	0.00%	0.02%
5D - Other waste	CH <sub>4</sub>	7.30	3.85	12.00%	25.00%	27.73%	0.01%	0.02%	0.03%	0.00%	0.01%	0.01%
5D - Other waste	N <sub>2</sub> O	8.86	7.57	12.00%	50.00%	51.42%	0.04%	0.00%	0.06%	0.00%	0.01%	0.01%

					level uncertainty in total inventory:				trend uncertainty:
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A	B	C	D	E	F	G	H	I	J	K	L	M
Key IPCC Source Categories	Gas	1990 (BY) emissions (1995 for F-gases)	2014 emissions	AD uncertainty	EF uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in 2014	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		<i>Gg CO2 equivalent</i>		%	%	%	%	%	%	%	%	%
<b>Total excl. LULUCF</b>	<b>CO2e</b>	<b>12887.74</b>	<b>10770.55</b>				<b>2.03%</b>					<b>1.24%</b>

Table 1-12 – Results of the Tier 1 uncertainty analysis including LULUCF.

A	B	C	D	E	F	G	H	I	J	K	L	M
Key IPCC Source Categories	Gas	1990 (BY) emissions (1995 for F-gases)	2014 emissions	AD uncertainty	EF uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in 2014	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		<i>Gg CO2 equivalent</i>		%	%	%	%	%	%	%	%	%
1A Stationary Combustion - Gaseous Fuels	CO2	1039.13	2113.72	0.50%	0.50%	0.71%	0.14%	9.65%	16.40%	0.05%	0.12%	0.13%
1A Stationary Combustion - Gaseous Fuels	CH4	1.04	2.29	0.50%	50.00%	50.00%	0.01%	0.01%	0.02%	0.01%	0.00%	0.01%
1A Stationary Combustion - Gaseous Fuels	N2O	0.54	1.11	0.50%	50.00%	50.00%	0.01%	0.01%	0.01%	0.00%	0.00%	0.00%

A	B	C	D	E	F	G	H	I	J	K	L	M
Key IPCC Source Categories	Gas	1990 (BY) emissions (1995 for F-gases)  Gg CO2 equivalent	2014 emissions	AD uncertainty	EF uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in 2014	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
				%	%	%	%	%	%	%	%	%
1A Stationary Combustion - Liquid Fuels	CO2	1274.48	822.24	2.00%	0.50%	2.06%	0.16%	1.88%	6.38%	0.01%	0.18%	0.18%
1A Stationary Combustion - Liquid Fuels	CH4	3.48	2.19	2.00%	50.00%	50.04%	0.01%	0.01%	0.02%	0.00%	0.00%	0.00%
1A Stationary Combustion - Liquid Fuels	N2O	14.85	10.44	2.00%	50.00%	50.04%	0.05%	0.02%	0.08%	0.01%	0.00%	0.01%
1A Stationary Combustion - Other Fuels	CO2	33.29	114.10	7.00%	20.00%	21.19%	0.22%	0.67%	0.89%	0.13%	0.09%	0.16%
1A Stationary Combustion - Other Fuels	CH4	0.25	0.94	7.00%	50.00%	50.49%	0.00%	0.01%	0.01%	0.00%	0.00%	0.00%
1A Stationary Combustion - Other Fuels	N2O	0.40	1.50	7.00%	50.00%	50.49%	0.01%	0.01%	0.01%	0.00%	0.00%	0.00%
1A Stationary Combustion - Biomass	CH4	5.50	8.34	10.00%	50.00%	50.99%	0.04%	0.03%	0.06%	0.01%	0.01%	0.02%
1A Stationary Combustion - Biomass	N2O	1.81	3.56	10.00%	50.00%	50.99%	0.02%	0.02%	0.03%	0.01%	0.00%	0.01%

A	B	C	D	E	F	G	H	I	J	K	L	M
Key IPCC Source Categories	Gas	1990 (BY) emissions (1995 for F-gases)  Gg CO2 equivalent	2014 emissions	AD uncertainty  %	EF uncertainty  %	Combined uncertainty  %	Combined uncertainty as % of total national emissions in 2014  %	Type A sensitivity  %	Type B sensitivity  %	Uncertainty in trend in national emissions introduced by emission factor uncertainty  %	Uncertainty in trend in national emissions introduced by activity data uncertainty  %	Uncertainty introduced into the trend in total national emissions  %
1A Stationary Combustion - Solid Fuels	CO2	5317.44	185.90	3.00%	3.00%	4.24%	0.07%	32.90%	1.44%	0.99%	0.06%	0.99%
1A Stationary Combustion - Solid Fuels	CH4	5.40	0.64	3.00%	50.00%	50.09%	0.00%	0.03%	0.00%	0.02%	0.00%	0.02%
1A Stationary Combustion - Solid Fuels	N2O	5.94	0.88	3.00%	50.00%	50.09%	0.00%	0.03%	0.01%	0.02%	0.00%	0.02%
1A3a Transport - Civil Aviation	CO2	0.21	0.50	2.00%	0.50%	2.06%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1A3a Transport - Civil Aviation	CH4	0.00	0.00	2.00%	100.00%	100.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1A3a Transport - Civil Aviation	N2O	0.00	0.00	2.00%	150.00%	150.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1A3b - Road Transportation - Diesel Oil	CO2	1342.84	5082.52	1.00%	0.50%	1.12%	0.53%	30.70%	39.44%	0.15%	0.56%	0.58%
1A3b - Road Transportation - Diesel Oil	CH4	0.48	0.27	1.00%	20.00%	20.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1A3b - Road Transportation - Diesel Oil	N2O	2.65	46.07	1.00%	20.00%	20.02%	0.09%	0.34%	0.36%	0.07%	0.01%	0.07%



A	B	C	D	E	F	G	H	I	J	K	L	M
Key IPCC Source Categories	Gas	1990 (BY) emissions (1995 for F-gases)  Gg CO2 equivalent	2014 emissions	AD uncertainty  %	EF uncertainty  %	Combined uncertainty  %	Combined uncertainty as % of total national emissions in 2014  %	Type A sensitivity  %	Type B sensitivity  %	Uncertainty in trend in national emissions introduced by emission factor uncertainty  %	Uncertainty in trend in national emissions introduced by activity data uncertainty  %	Uncertainty introduced into the trend in total national emissions  %
1A3b - Road Transportation - Gasoline	CO2	1277.48	945.94	1.00%	0.50%	1.12%	0.10%	0.94%	7.34%	0.00%	0.10%	0.10%
1A3b - Road Transportation - Gasoline	CH4	10.93	1.85	1.00%	20.00%	20.02%	0.00%	0.06%	0.01%	0.01%	0.00%	0.01%
1A3b - Road Transportation - Gasoline	N2O	13.21	2.98	1.00%	20.00%	20.02%	0.01%	0.06%	0.02%	0.01%	0.00%	0.01%
1A3b - Road Transportation - LPG	CO2	11.34	4.03	10.00%	20.00%	22.36%	0.01%	0.04%	0.03%	0.01%	0.00%	0.01%
1A3b - Road Transportation - LPG	CH4	0.09	0.01	10.00%	50.00%	50.99%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1A3b - Road Transportation - LPG	N2O	0.13	0.01	10.00%	50.00%	50.99%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1A3c - Railways	CO2	24.72	10.13	2.00%	0.50%	2.06%	0.00%	0.08%	0.08%	0.00%	0.00%	0.00%
1A3c - Railways	CH4	0.03	0.01	2.00%	50.00%	50.04%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1A3c - Railways	N2O	2.85	1.17	2.00%	140.00%	140.01%	0.02%	0.01%	0.01%	0.01%	0.00%	0.01%

A	B	C	D	E	F	G	H	I	J	K	L	M
Key IPCC Source Categories	Gas	1990 (BY) emissions (1995 for F-gases)  <i>Gg CO2 equivalent</i>	2014 emissions	AD uncertainty  %	EF uncertainty  %	Combined uncertainty  %	Combined uncertainty as % of total national emissions in 2014  %	Type A sensitivity  %	Type B sensitivity  %	Uncertainty in trend in national emissions introduced by emission factor uncertainty  %	Uncertainty in trend in national emissions introduced by activity data uncertainty  %	Uncertainty introduced into the trend in total national emissions  %
1A3d - Navigation	CO2	0.97	1.07	2.00%	0.50%	2.06%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%
1A3d - Navigation	CH4	0.00	0.00	2.00%	50.00%	50.04%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1A3d - Navigation	N2O	0.01	0.01	2.00%	140.00%	140.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1A3d - Navigation	CO2	0.30	0.14	1.00%	0.50%	1.12%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1A3d - Navigation	CH4	0.01	0.00	1.00%	50.00%	50.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1A3d - Navigation	N2O	0.00	0.00	1.00%	140.00%	140.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1B2b - Fugitive Emission from Natural Gas	CO2	0.03	0.05	1.00%	0.50%	1.12%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1B2b - Fugitive Emission from Natural Gas	CH4	19.36	38.42	1.00%	40.00%	40.01%	0.14%	0.17%	0.30%	0.07%	0.00%	0.07%
2A1 - Cement Production	CO2	569.88	353.79	1.50%	2.50%	2.92%	0.10%	0.95%	2.75%	0.02%	0.06%	0.06%
2A3 - Glass Production	CO2	53.57	61.07	1.50%	5.00%	5.22%	0.03%	0.13%	0.47%	0.01%	0.01%	0.01%
2C1 - Iron & Steel Production	CO2	984.91	102.46	3.00%	1.00%	3.16%	0.03%	5.59%	0.80%	0.06%	0.03%	0.07%

A	B	C	D	E	F	G	H	I	J	K	L	M
Key IPCC Source Categories	Gas	1990 (BY) emissions (1995 for F-gases)  Gg CO2 equivalent	2014 emissions	AD uncertainty  %	EF uncertainty  %	Combined uncertainty  %	Combined uncertainty as % of total national emissions in 2014  %	Type A sensitivity  %	Type B sensitivity  %	Uncertainty in trend in national emissions introduced by emission factor uncertainty  %	Uncertainty in trend in national emissions introduced by activity data uncertainty  %	Uncertainty introduced into the trend in total national emissions  %
2D1 - Lubricant use	CO2	6.20	4.37	5.00%	50.00%	50.25%	0.02%	0.01%	0.03%	0.00%	0.00%	0.00%
2D2 Paraffin wax use	CO2	0.21	1.70	5.00%	100.00%	100.12%	0.02%	0.01%	0.01%	0.01%	0.00%	0.01%
2D3 - solvent use	CO2	23.90	10.96	50.00%	50.00%	70.71%	0.07%	0.07%	0.09%	0.03%	0.06%	0.07%
2D3 - urea-based catalysts	CO2	0.00	9.42	20.00%	5.00%	20.62%	0.02%	0.07%	0.07%	0.00%	0.02%	0.02%
2F - Product Uses as Substitutes for ODS	F-gases	17.90	64.37	30.00%	20.00%	36.06%	0.22%	0.38%	0.50%	0.08%	0.21%	0.23%
2G - Other Product Manufacture and Use	F-gases	1.39	10.11	30.00%	20.00%	36.06%	0.03%	0.07%	0.08%	0.01%	0.03%	0.04%
2G - Other Product Manufacture and Use	N2O	7.28	27.48	20.00%	20.00%	28.28%	0.07%	0.17%	0.21%	0.03%	0.06%	0.07%
3A1 - Enteric Ferm. - Cattle	CH4	428.44	407.70	2.00%	20.00%	20.10%	0.76%	0.39%	3.16%	0.08%	0.09%	0.12%
3A2 - Enteric Ferm. - Sheep	CH4	1.78	2.13	10.00%	30.00%	31.62%	0.01%	0.01%	0.02%	0.00%	0.00%	0.00%

A	B	C	D	E	F	G	H	I	J	K	L	M
Key IPCC Source Categories	Gas	1990 (BY) emissions (1995 for F-gases)  Gg CO2 equivalent	2014 emissions	AD uncertainty  %	EF uncertainty  %	Combined uncertainty  %	Combined uncertainty as % of total national emissions in 2014  %	Type A sensitivity  %	Type B sensitivity  %	Uncertainty in trend in national emissions introduced by emission factor uncertainty  %	Uncertainty in trend in national emissions introduced by activity data uncertainty  %	Uncertainty introduced into the trend in total national emissions  %
3A3 - Enteric Ferm. - Swine	CH4	2.83	3.27	5.00%	30.00%	30.41%	0.01%	0.01%	0.03%	0.00%	0.00%	0.00%
3A4 - Enteric Ferm. - Other livestock	CH4	0.98	2.80	10.00%	30.00%	31.62%	0.01%	0.02%	0.02%	0.00%	0.00%	0.01%
3B1.1 - Manure Man. - Cattle	CH4	40.93	49.23	2.00%	70.00%	70.03%	0.32%	0.12%	0.38%	0.08%	0.01%	0.08%
3B1.2 - Manure Man. - Sheep	CH4	0.04	0.05	10.00%	70.00%	70.71%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
3B1.3 - Manure Man. - Swine	CH4	10.87	11.39	5.00%	70.00%	70.18%	0.07%	0.02%	0.09%	0.01%	0.01%	0.01%
3B1.4 - Manure Man. - Other livestock	CH4	0.13	0.31	10.00%	70.00%	70.71%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
3B2 - Manure Management	N2O	39.08	34.76	15.00%	100.00%	101.12%	0.33%	0.02%	0.27%	0.38%	0.06%	0.39%
3D1 - Agric. Soils - direct N2O emissions from managed soils	N2O	139.48	113.00	10.00%	150.00%	150.33%	1.58%	0.03%	0.88%	0.04%	0.12%	0.13%
3D2 - Agric. Soils - indirect N2O emissions from managed soils	N2O	50.06	41.49	10.00%	150.00%	150.33%	0.58%	0.00%	0.32%	0.00%	0.05%	0.05%

A	B	C	D	E	F	G	H	I	J	K	L	M
Key IPCC Source Categories	Gas	1990 (BY) emissions (1995 for F-gases)  Gg CO2 equivalent	2014 emissions	AD uncertainty  %	EF uncertainty  %	Combined uncertainty  %	Combined uncertainty as % of total national emissions in 2014  %	Type A sensitivity  %	Type B sensitivity  %	Uncertainty in trend in national emissions introduced by emission factor uncertainty  %	Uncertainty in trend in national emissions introduced by activity data uncertainty  %	Uncertainty introduced into the trend in total national emissions  %
3G - Liming	N2O	0.59	5.81	20.00%	150.00%	151.33%	0.08%	0.04%	0.05%	0.06%	0.01%	0.06%
4 - Land Use, Land-Use Change and Forestry	CO2, N2O	52.13	460.44			42.30%	1.81%	3.23%	3.57%	0.00%	0.00%	0.00%
5A - Solid Waste disposal on Land	CH4	79.92	28.87	12.00%	25.00%	27.73%	0.07%	0.29%	0.22%	0.07%	0.04%	0.08%
5B - Wastewater handling	CH4	0.00	5.57	10.00%	50.00%	50.99%	0.03%	0.04%	0.04%	0.02%	0.01%	0.02%
5B - Wastewater handling	N2O	0.00	3.98	10.00%	50.00%	50.99%	0.02%	0.03%	0.03%	0.02%	0.00%	0.02%
5D - Other waste	CH4	7.30	3.85	12.00%	25.00%	27.73%	0.01%	0.02%	0.03%	0.00%	0.01%	0.01%
5D - Other waste	N2O	8.86	7.57	12.00%	50.00%	51.42%	0.04%	0.00%	0.06%	0.00%	0.01%	0.01%
					level uncertainty in total inventory:							trend uncertainty:
Total excl. LULUCF	CO2e	12939.88	11230.99				2.72%					1.30%

### **1.7.2 KP-LULUCF inventory**

Uncertainties of emissions/removals of the ARD units have not been assessed in submission 2016v1. Depending on the availability of the necessary funds, both financial and human, an uncertainty assessment of the ARD units might be feasible for the 2017 submission.

## **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 2014. 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 2016v1. 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 as well as indirect GHG – NO<sub>x</sub>, CO, NMVOCs – and SO<sub>2</sub> 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 22<sup>nd</sup> 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.

#### **1.8.1.5 Transparency and completeness indexes**

Transparency and completeness indexes are calculated as follows:

- Transparency (*TR*) [%] =  $[1 - (\text{number of IE} / \text{number of estimates})] * 100$
- Completeness (*CP*) [%] =  $[1 - (\text{number of NE} / \text{number of estimates})] * 100$

However, due to the formatting issues generated by the current version of the CRF-Reporter, the reporting tables still contain errors (such as empty cells, or cells with wrong notation keys. Hence, transparency and completeness indexes were not performed.

#### **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 1<sup>st</sup> 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 km<sup>2</sup>. The maximum distance from North to South is some 82 km, from West to East about 57 km (Figure 2-2). In 2014, 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).

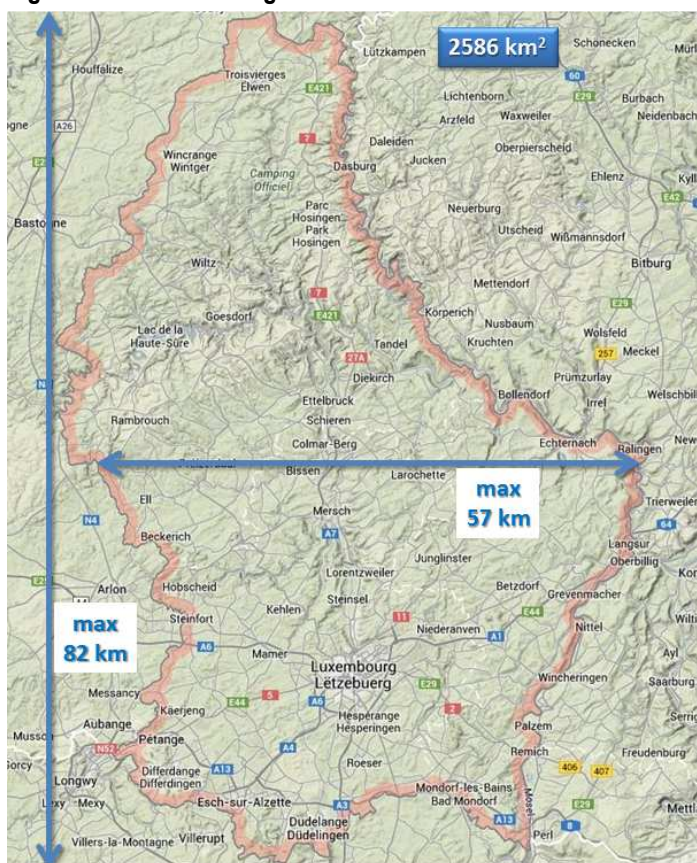
The North of Luxembourg is a part of the Ardennes and is called “Ösling”. Its altitude is at an average of 400 to 500 meters above sea level. The “Ösling” landscape is affected by hills and deep river valleys, as for instance the Sure (Sauer) river. With 560 m, the highest elevation is called the “Kneiff” 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: 1972-2014

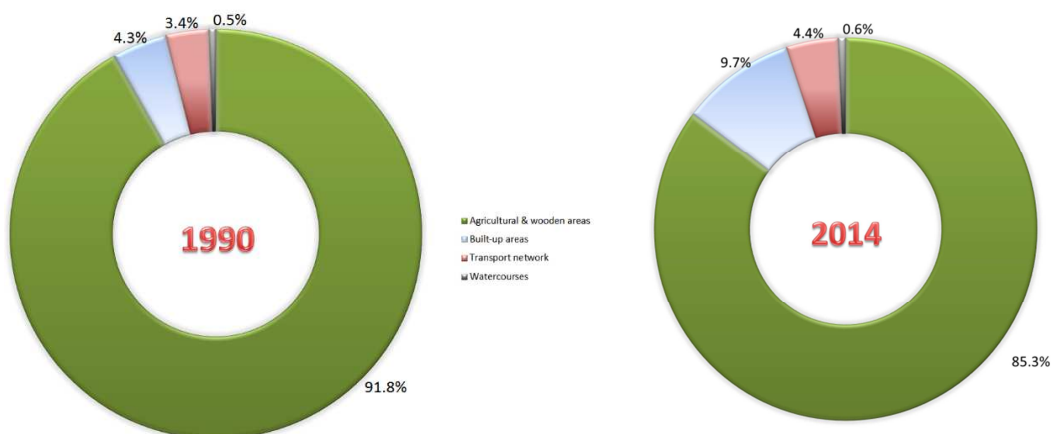
percentages	1972	1990	2000	2005	2010	2014
<b>Total land</b>	100.0	100.0	100.0	100.0	100.0	100.0
<b>Agricultural &amp; wooden area</b>	93.2	91.8	87.4	86.5	85.7	85.3
<b>Built-up area</b>	3.1	4.3	8.1	8.7	9.3	9.7
<i>of which industrial area &amp; other</i>	<i>n.a.</i>	<i>n.a.</i>	2.7	2.8	3.0	3.1
<b>Transport network &amp; sheets of water</b>	3.2	3.4	3.9	4.2	4.4	4.4
<b>Watercourses</b>	0.5	0.5	0.6	0.6	0.6	0.6

Source: STATEC, *Statistical Yearbook*, Table A.1101 (updated 5 April 2016):

[http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=137&IF\\_Language=fra&MainTheme=1&FldName=1](http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=137&IF_Language=fra&MainTheme=1&FldName=1).

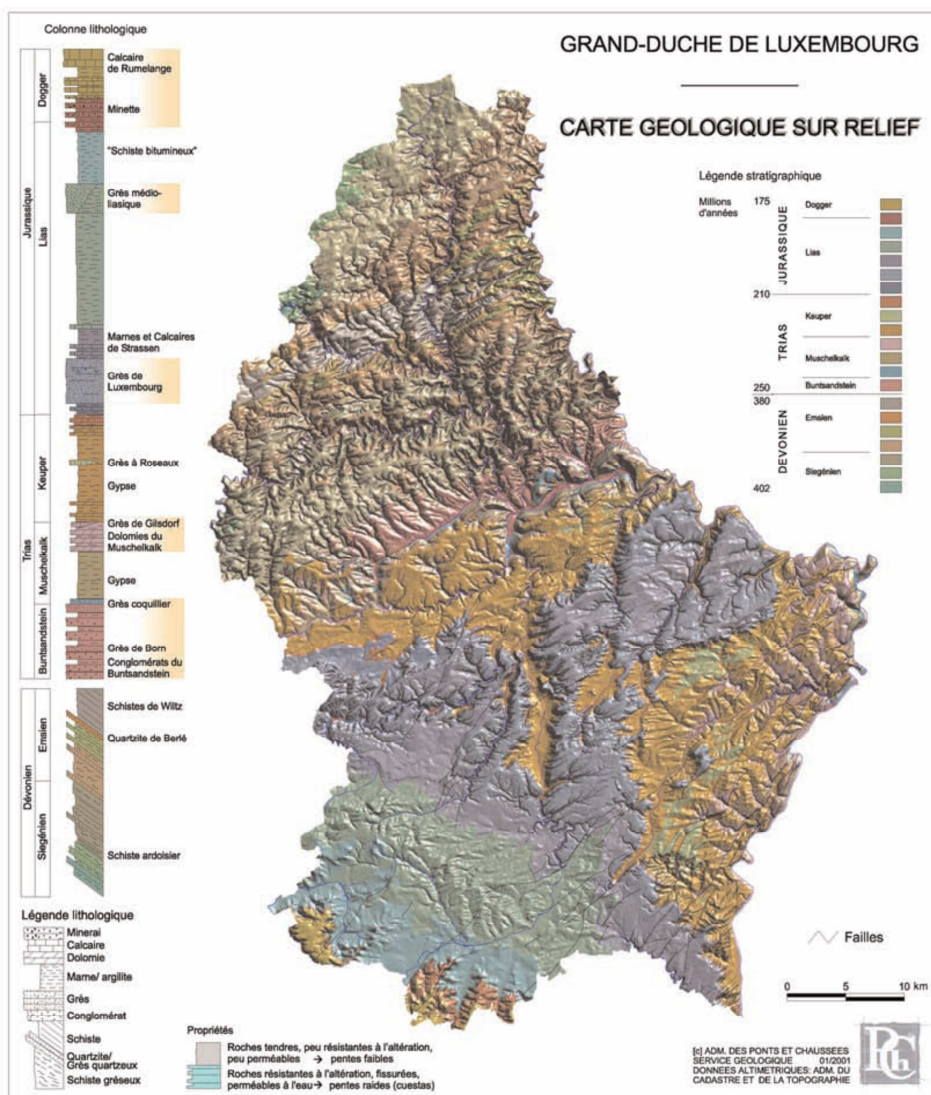


Figure 2-3 – Land use: 1990 & 2014



Source: STATEC, *Statistical Yearbook*, Table A.1101 (updated 5 April 2016): [http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=137&IF\\_Language=fr&MainTheme=1&FldrName=1](http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=137&IF_Language=fr&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 <sup>38</sup>

### 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),<sup>39</sup> 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).<sup>40</sup>

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.<sup>41</sup> 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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<sup>38</sup> 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*.

<sup>39</sup> <http://www.ana.public.lu/en/meteo/index.html>.

<sup>40</sup> See also a graphic representation (<http://meteolux.lu/fr/produits-et-services>).

<sup>41</sup> Ries, C. (éditeur) (2005), *Contribution à la climatologie du Luxembourg: analyses historiques, scénarios 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.<sup>42</sup>

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

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
<b>Average air temperature [°C]</b>	8.3	8.3	8.7	9.2
<b>Mean minimum air temperature [°C]</b>	4.6	4.7	5.1	5.6
<b>Mean maximum air temperature [°C]</b>	12.3	12.3	12.7	13.1
<b>Mean yearly precipitation sum [mm]</b>	819.6	874.5	862.4	869.9

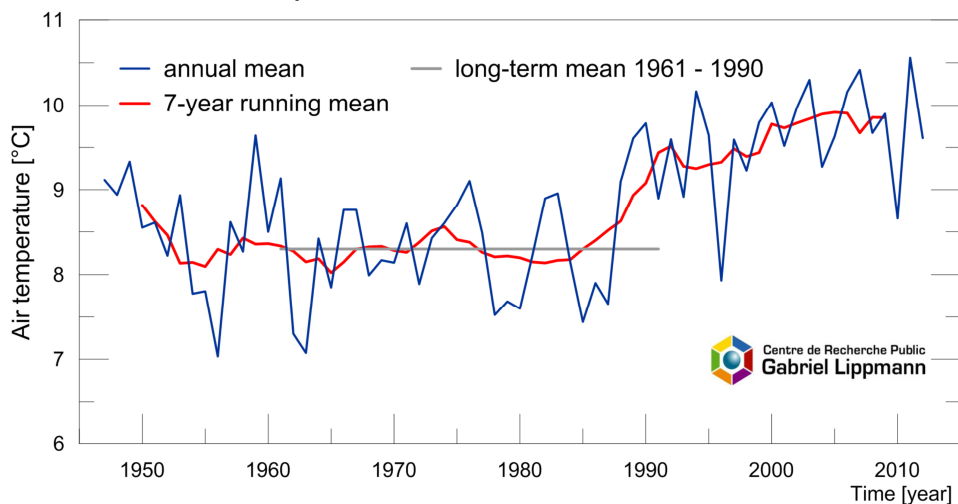
	1990	2000	2005	2010	2011	2014
<b>Average air temperature [°C]</b>	9.8	10.0	9.6	8.7	10.6	10.8
<b>Mean minimum air temperature [°C]</b>	6.0	6.5	n.a.	5.0	6.6	<b>5.9</b>
<b>Mean maximum air temperature [°C]</b>	13.8	13.8	n.a.	12.4	14.8	<b>13.5</b>
<b>Mean yearly precipitation sum [mm]</b>	1020.5	1036.4	718.2	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>.

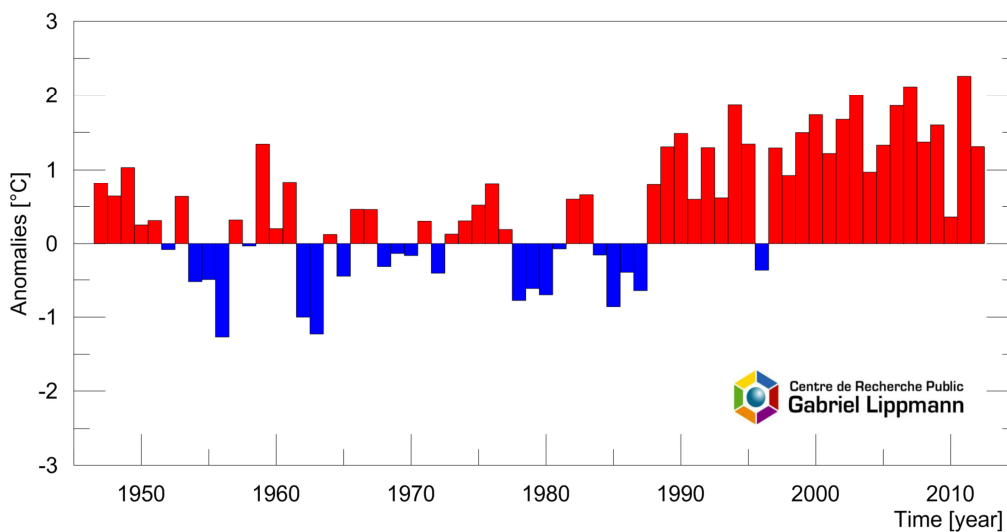
<sup>42</sup> Pfister, L., Hoffmann, L., and Humbert, J. (2000), *Recent Trends in Rainfall-Runoff Characteristics in the Alzette River Basin, Luxembourg* in *Climatic Change*, volume 45, Springer Netherlands, 323-337.  
Pfister, L., Drogue, G., El Idrissi, A., Iffly, J.F., Poirier, C., and Hoffmann, 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: 1947-2014**



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

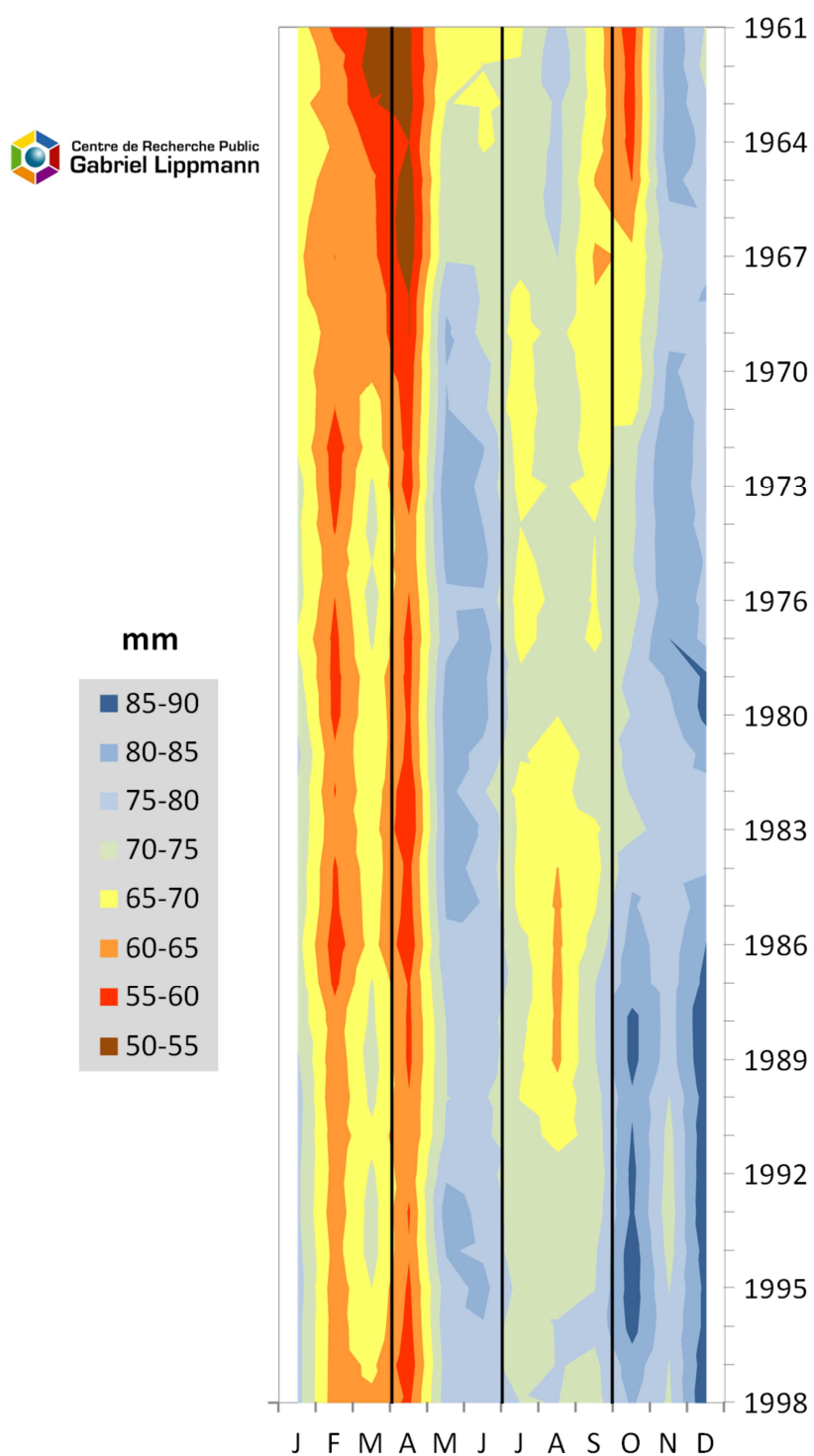
**Figure 2-6 – Anomalies of annual air temperature from the reference period 1961-1990 for the Findel-Airport station: 1947-2014**



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: 1947-2014



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

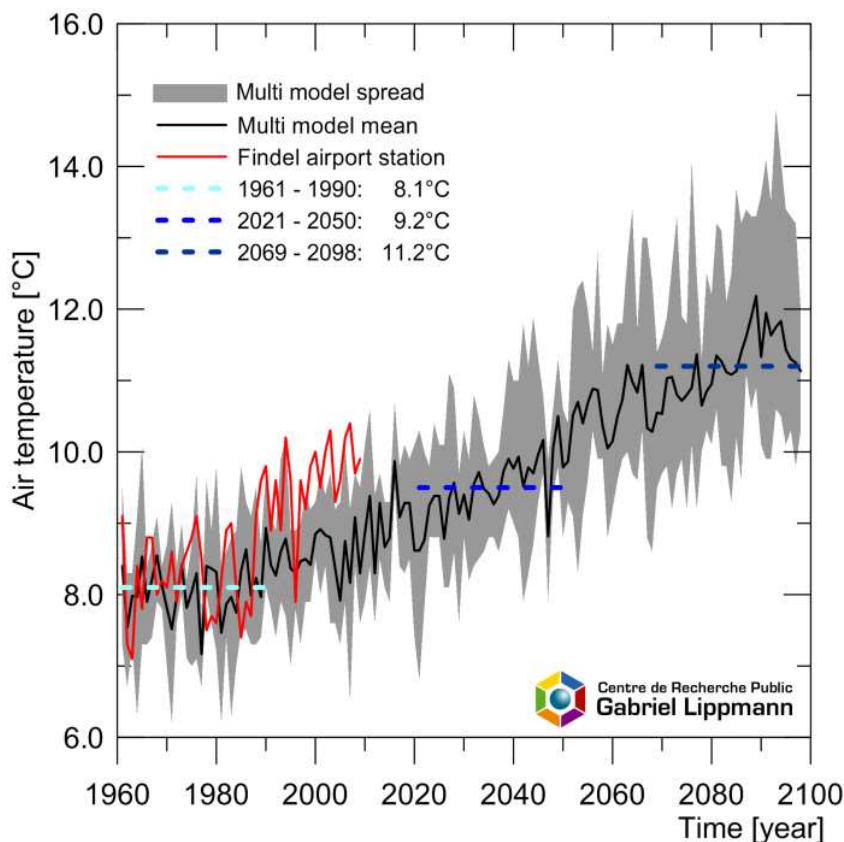


### 2.1.2.2 Climate projections: continuing rise in air temperature

Preliminary results taken from a project from the Department “Environment and Agrobiotechnology” 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,<sup>43</sup> 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).

Preliminary 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 21<sup>st</sup> 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**



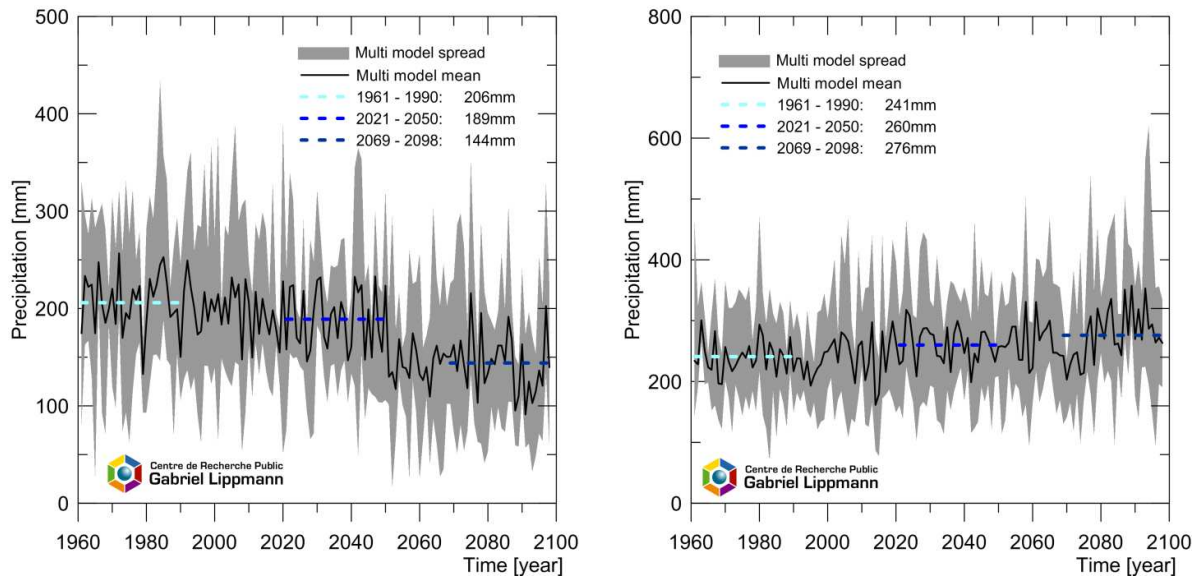
**Source:** Luxembourg Institute of Science and Technology, unpublished.

**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.

<sup>43</sup> <http://ensembles-eu.metoffice.com>.

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

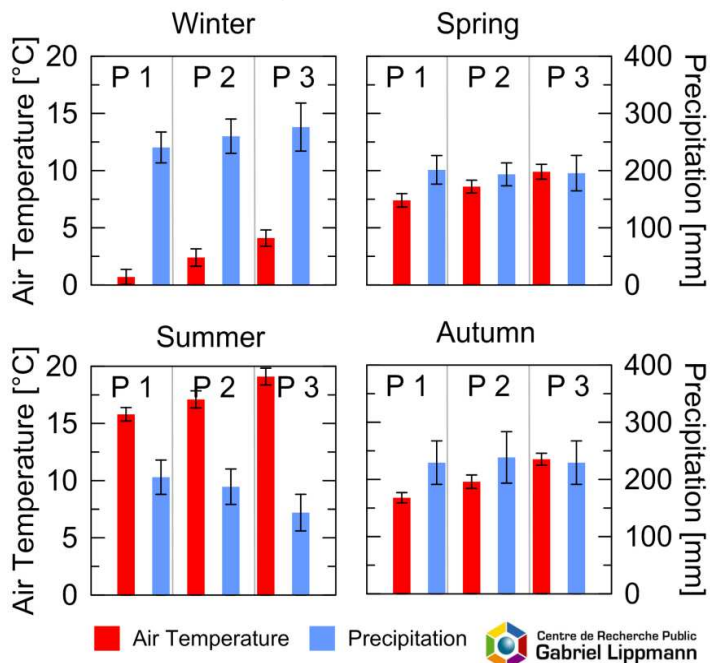


**Source:** Luxembourg Institute of Science and Technology.

**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,<sup>44</sup> 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.<sup>45</sup>

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.<sup>46</sup>

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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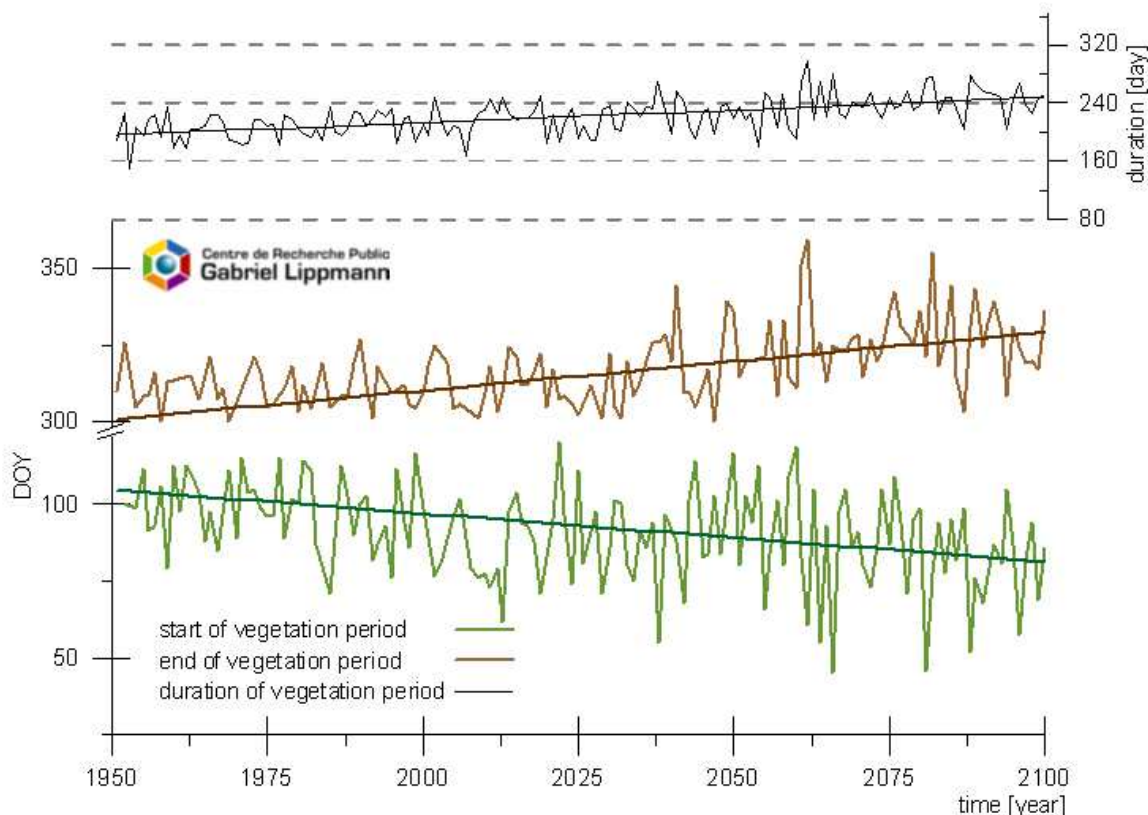
<sup>44</sup> European Environment Agency, (2012), *Climate change, impacts and vulnerability in Europe 2012 – An indicator-based report*, EEA Report No 12/2012, Copenhagen (<http://www.eea.europa.eu/publications/climate-impacts-and-vulnerability-2012>).

<sup>45</sup> Chmielewski, F.M., and Rötzer, T. (2001), *Response of tree phenology to climate change across Europe*. In *Agricultural and Forest Meteorology*, 108, 101-112.

<sup>46</sup> 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.<sup>47</sup> This is why an observation hydro-climatic network (*réseau d'observation hydro-climatologique*) has been put in place in the mid-1990s.<sup>48</sup> 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.<sup>49</sup>

### 2.1.3 Population and Workforce

#### 2.1.3.1 A strong population growth driven by immigration

At the end of 2014, the **population of Luxembourg** amounted to 549 700 inhabitants. Within slightly more than 50 years, the residential population has grown by some 234 800 inhabitants or about 78.8% – 46.5% 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 2014, the average annual growth rate for Luxembourg (1.5%) was about 4 times lower than its equivalent for the *Grande Région*.<sup>50</sup> 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 2014, 45.3% 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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<sup>47</sup> 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>)

<sup>48</sup> <http://www.hydroclimato.lu>.

<sup>49</sup> For an example, look at <http://www.luxnatur.lu/alzrena1.htm>.

<sup>50</sup> Refer to Box 2-1 for a presentation of the *Grande Région*.

living in Luxembourg by 2050 (Figure 2-13).<sup>51</sup> 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.

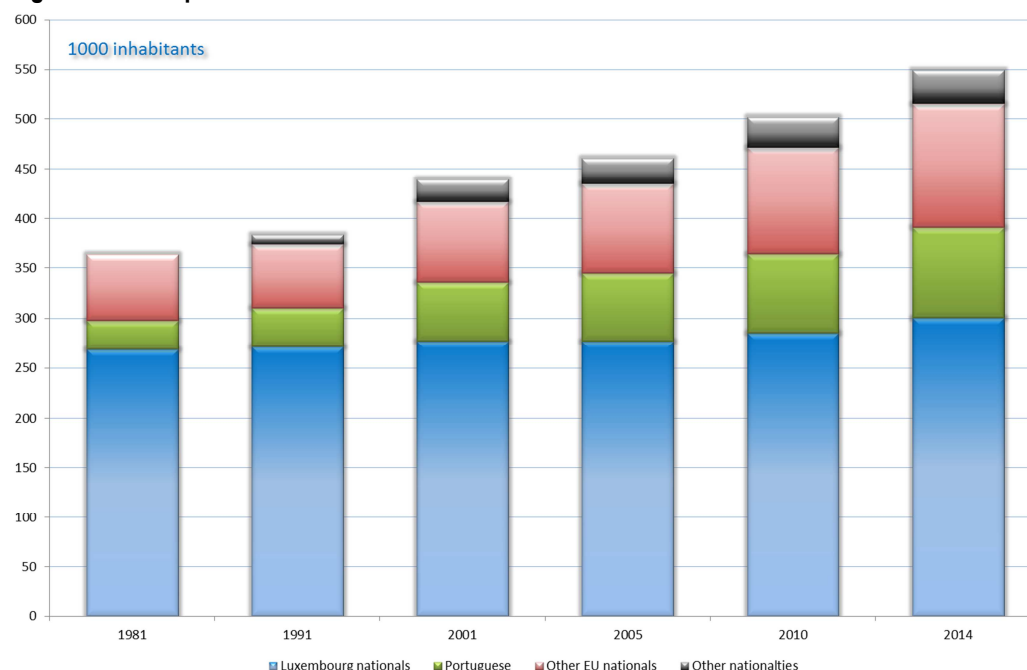
**Table 2-4 – Population: 1960-2014**

calculated on 31 <sup>st</sup> December	1960	1990	1995	2000	2005	2010	2014
<b>Resident population (x 1000)</b>	314.9	379.3	405.7	433.6	469.1	502.1	549.7

Source: STATEC, *Statistical Yearbook*, Table B.1100 (updated 4 April 2016):

[http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=383&IF\\_Language=fra&MainTheme=2&FldrName=1](http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=383&IF_Language=fra&MainTheme=2&FldrName=1).

**Figure 2-12 – Population structure on 31<sup>st</sup> December: 1981-2014**



Source: STATEC, *Statistical Yearbook*, Table B.1101 (updated 25 February 2016):

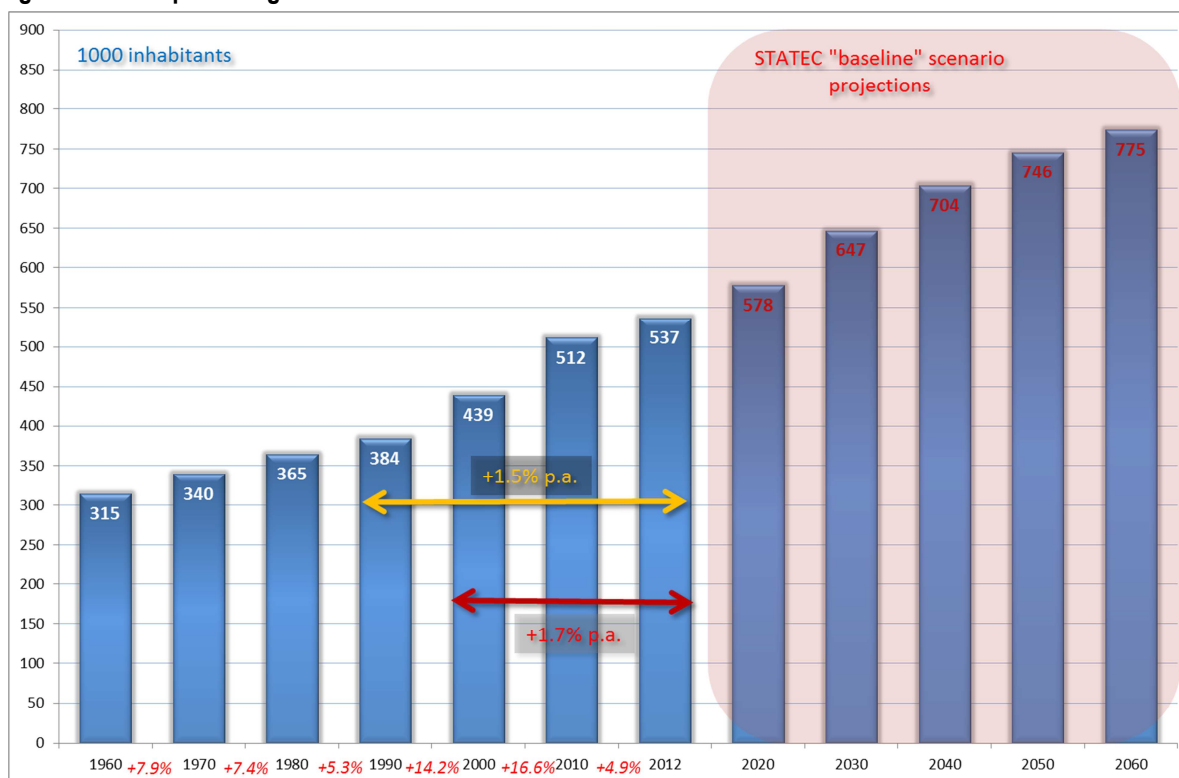
[http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=384&IF\\_Language=fra&MainTheme=2&FldrName=1](http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=384&IF_Language=fra&MainTheme=2&FldrName=1).

Note: 1981, 1991 and 2001 data are coming from population censuses held every decade, other years are calculated by STATEC.

<sup>51</sup> 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](http://europa.eu/epc/working_groups/ageing_en.htm) and [http://europa.eu/epc/pdf/2012\\_ageing\\_report\\_en.pdf](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](http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Population_projections).



Figure 2-13 – Population growth on 31<sup>st</sup> December: 1960-2060



Sources: STATEC, *Statistical Yearbook*, Table B.1100 (updated 4 April 2016):  
[http://www.statistiques.public.lu/stat/TableView/tableView.aspx?ReportId=383&IF\\_Language=fr&MainTheme=2&FldrName=1](http://www.statistiques.public.lu/stat/TableView/tableView.aspx?ReportId=383&IF_Language=fr&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.

<i>Grande Région</i> entity	Population change (1st January) % 1990-2014	Population annual average growth rate (1st January) % 1990-2014	GDP at current price annual average growth rate % 1990-2014	Total employment in 2014 1990=100
BE-Wallonia	10.26%	4.41%	10.33%	4.94%
DE-Rheinland-Pfalz	7.91%	4.32%	6.97%	4.81%
DE-Saarland	-6.97%	3.72%	6.76%	4.39%
FR-Lorraine	1.82%	4.07%	6.93%	4.38%
Luxembourg	44.92%	5.80%	19.86%	8.73%

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 140 400 in 2014, representing an average annual growth rate of only 2%. 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 89 900 in 2014 – an average annual growth rate of 3%. But, this was not enough. So the **cross-border commuters** came into play. Between 1995 and 2014, the number of cross-border workers increased from 56 900 to 165 300, at an average annual growth rate of 6% (Table 2-5).<sup>52</sup>

For 2014, among the persons employed, 49.7% of the commuters came from France, 25.2% from Germany and 25.1% from Belgium. In total, the commuters accounted for 42% of the total workforce in Luxembourg and for 39% (*i.e.* more than a quarter) of the residential population (Figure 2-14).<sup>53</sup> 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.<sup>54</sup> 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: 1995-2014**

<i>in thousand persons</i>	1995	2000	2005	2010	2014
<b>Resident workers – Lux. nationals</b> <small>(B.3106 &amp; E.2309)</small>	103.70	106.50	108.50	117.80	140.40
<b>Resident workers – foreigners</b> <small>(B.3106 &amp; B.3107)</small>	54.90	67.20	77.90	89.70	89.90
<b>Cross-border workers</b> <small>(B.3107)</small>	56.90	90.30	121.20	151.90	165.30
<b>Total workers/employment</b> <small>(E.2309)</small>	215.50	264.00	307.60	359.40	395.60

Sources: Environment Agency calculations on the basis of STATEC, *Statistical Yearbook*, Table B.3106 (updated 28 October 2013), B.3107 (updated 24 February 2016) & E.2309 (updated 24 February 2016):

[http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=493&IF\\_Language=fra&MainTheme=2&FldrName=3&RFPPath=92](http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=493&IF_Language=fra&MainTheme=2&FldrName=3&RFPPath=92)  
[http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=494&IF\\_Language=fra&MainTheme=2&FldrName=3&RFPPath=92](http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=494&IF_Language=fra&MainTheme=2&FldrName=3&RFPPath=92)  
[http://www.statistiques.public.lu/stat/TableViewer/document.aspx?ReportId=1497&IF\\_Language=fra&MainTheme=5&FldrName=2](http://www.statistiques.public.lu/stat/TableViewer/document.aspx?ReportId=1497&IF_Language=fra&MainTheme=5&FldrName=2)

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.

<sup>52</sup> Figures indicated in this paragraph are annual cumulative averages.

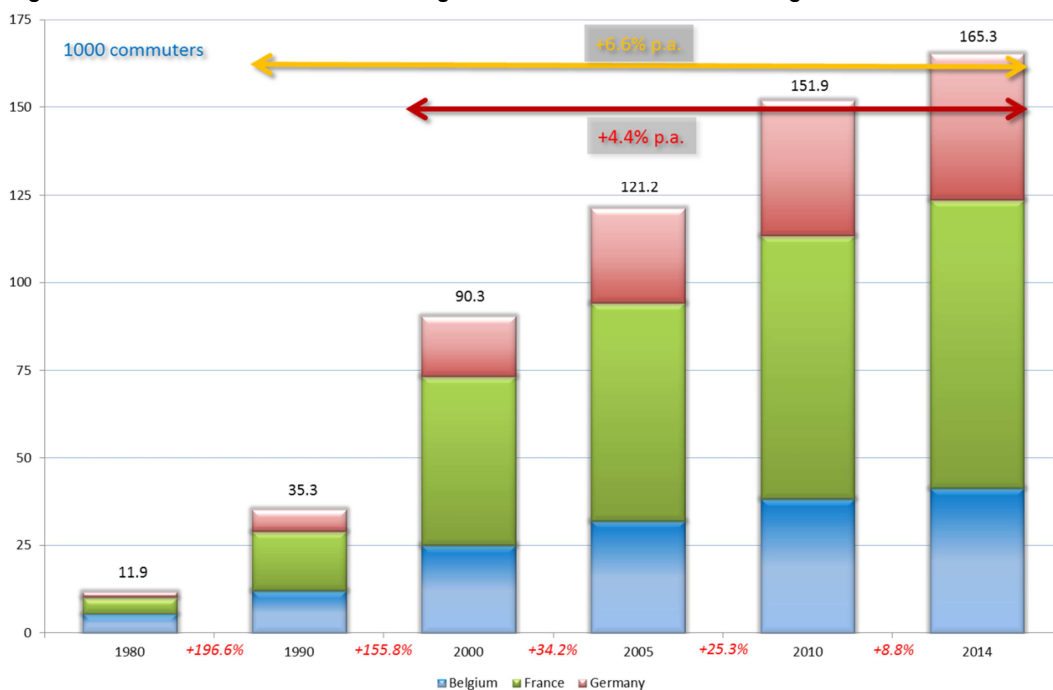
<sup>53</sup> Calculated from STATEC, *Statistical Yearbook*, Table B.3107:

[http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=494&IF\\_Language=fra&MainTheme=2&FldrName=3&RFPPath=92](http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=494&IF_Language=fra&MainTheme=2&FldrName=3&RFPPath=92).

<sup>54</sup> 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>.

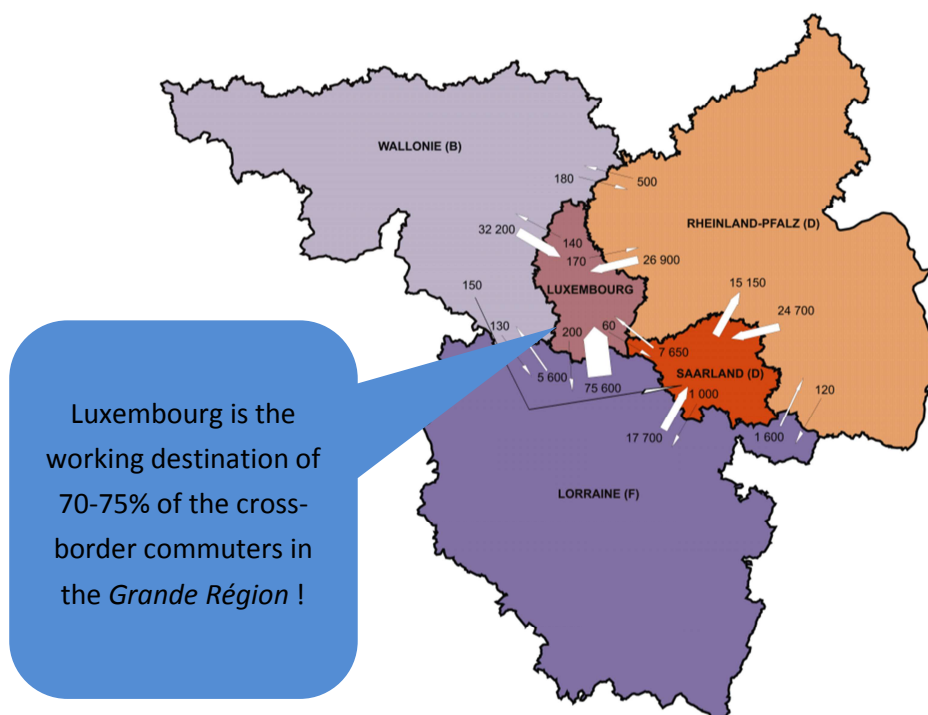


**Figure 2-14 – Cross-border commuters' growth: annual cumulative averages 1980-2014**



Source: STATEC, *Statistical Yearbook*, Table B.3107 (updated 24 February 2016):  
[http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=494&IF\\_Language=fra&MainTheme=2&FldrName=3&RFPPath=92](http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=494&IF_Language=fra&MainTheme=2&FldrName=3&RFPPath=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&RFPPath=92](http://www.statistiques.public.lu/stat/TableViewer/document.aspx?ReportId=498&IF_Language=fra&MainTheme=2&FldrName=3&RFPPath=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 2014.<sup>55</sup> 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 less than 6.5% in 2014. Other service activities ranged between a share of 20 to 25% and construction kept a rather constant share in total gross value added between 7 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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<sup>55</sup> Data prior to 1995 are and will not be translated into the new European System of Accounts (ESA).

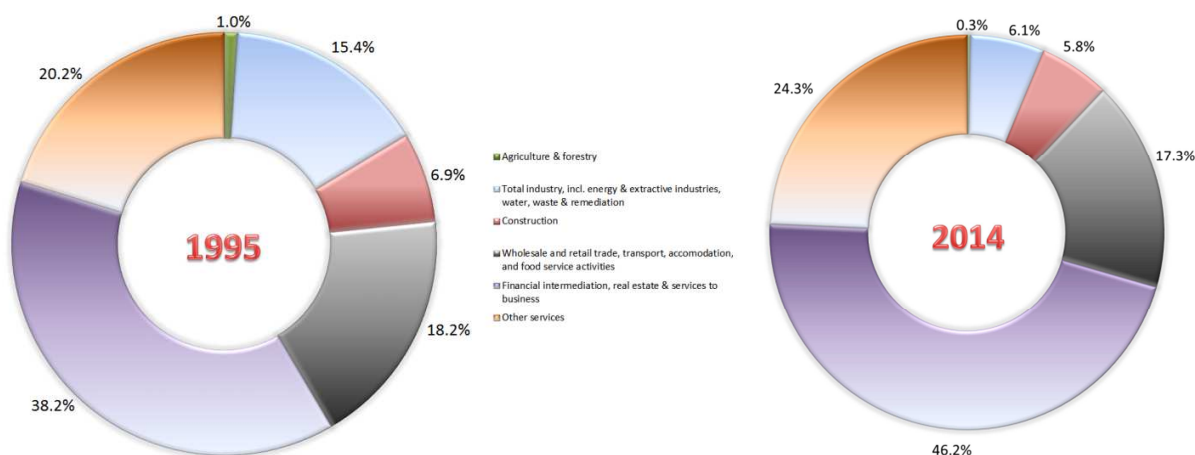
- due to its size and the size of its energy and industrial sector, structural changes in these sectors that could be initiated by a single entity;
- road transportation related fuel sales: more on this in Section 2.1.6.

**Table 2-6 – Sectoral gross value added at current prices: 1995-2014**

mio. EUR	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
<b>Agriculture, forestry &amp; fishing (A)</b>	140.6	143.6	106.8	114.3	152.3	118.9	93.0	100.0	107.3	157.8	122.5	130.0
%	1.0%	0.7%	0.4%	0.4%	0.5%	0.4%	0.3%	0.3%	0.3%	0.4%	0.3%	0.3%
<b>Total industry, including extractive industries, energy production &amp; distribution, water supply, sewerage, waste management and remediation activities (B to E)</b>	2103.5	2575.2	2877.2	2947.3	3582.7	3245.0	2299.3	2654.9	2702.9	2697.7	2620.2	2649.5
%	15.4%	12.4%	10.8%	9.8%	10.8%	9.6%	7.1%	7.4%	7.1%	6.9%	6.3%	6.1%
<b>Construction (F)</b>	947.0	1242.3	1531.4	1670.3	1925.6	1937.0	1911.8	1943.2	2191.0	2080.2	2270.0	2529.8
%	6.9%	6.0%	5.8%	5.6%	5.8%	5.7%	5.9%	5.4%	5.8%	5.3%	5.4%	5.8%
<b>Wholesale and retail trade, transport, accommodation and food service activities (G to I)</b>	2492.1	3530.5	4227.0	4713.9	4830.5	5793.9	5213.9	6040.5	6814.3	6823.8	7127.9	7546.5
%	18.2%	17.0%	15.9%	15.7%	14.6%	17.1%	16.0%	16.9%	17.9%	17.5%	17.1%	17.3%
<b>Financial and insurance activities; real estate activities; professional, scientific and technical activities; administrative and support service activities (K to N)</b>	5225.0	9092.6	11765.8	14177.6	15558.2	15410.3	15327.6	16566.6	17205.8	17701.9	19429.5	20167.7
%	38.2%	43.7%	44.4%	47.1%	47.1%	45.5%	47.0%	46.4%	45.3%	45.3%	46.6%	46.2%
<b>Other services: information and communication; public administration, defence, education, human health and social work activities; arts, entertainment and recreation; Other service activities; activities of household (J &amp; O to U)</b>	2764.9	4243.8	6010.5	6470.7	6985.6	7383.9	7755.7	8377.8	8996.2	9630.5	10166.0	10610.0
%	20.2%	20.4%	22.7%	21.5%	21.1%	21.8%	23.8%	23.5%	23.7%	24.6%	24.4%	24.3%
<b>Total: all NACE rev2 branches</b>	<b>13672.9</b>	<b>20828.1</b>	<b>26518.7</b>	<b>30094.2</b>	<b>33034.9</b>	<b>33889.1</b>	<b>32601.5</b>	<b>35683.0</b>	<b>38017.4</b>	<b>39091.9</b>	<b>41736.0</b>	<b>43633.3</b>
<b>Annual growth rate - current prices</b>				13.5%	9.8%	2.6%	-3.8%	9.5%	6.5%	2.8%	6.8%	4.5%
<b>Annual growth rate - constant prices/in volume</b>				5.6%	8.5%	-1.1%	-5.7%	6.0%	2.0%	-1.2%	4.2%	3.6%

Source: STATEC, *Statistical Yearbook*, Tables E.2304 (current prices) & E.2305 (constant prices) (updated 24 February 2016): [http://www.statistiques.public.lu/stat/TableViewer/document.aspx?ReportId=1497&IF\\_Language=fra&MainTheme=5&FldrName=2](http://www.statistiques.public.lu/stat/TableViewer/document.aspx?ReportId=1497&IF_Language=fra&MainTheme=5&FldrName=2)

**Figure 2-16 – Sectoral gross value added at current prices: 1995 & 2014**



Source: STATEC, *Statistical Yearbook*, Table E.2304 (updated 24 February 2016): [http://www.statistiques.public.lu/stat/TableViewer/document.aspx?ReportId=1497&IF\\_Language=fra&MainTheme=5&FldrName=2](http://www.statistiques.public.lu/stat/TableViewer/document.aspx?ReportId=1497&IF_Language=fra&MainTheme=5&FldrName=2)

## 2.1.5 Energy

### 2.1.5.1 A total change in Luxembourg's energy-mix

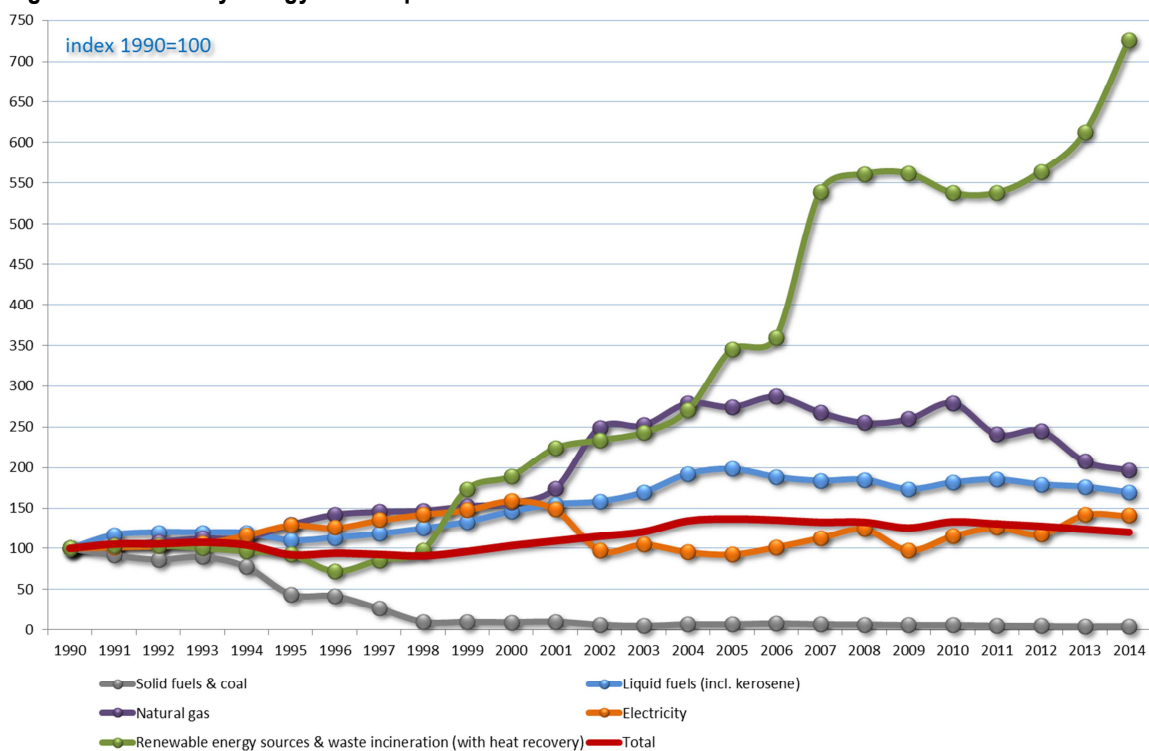
Primary and final energy consumption in Luxembourg experienced dramatic changes since 1990. Overall **primary energy consumption** increased by 19.9% between 1990 and 2014. Whereas solid fuels and coal declined by more than 95% over the period, liquid fuels (incl. kerosene) and natural gas consumptions increased by 169% and 196% respectively (Table 2-7 & Figure 2-17).

**Table 2-7 – Primary energy consumption: 1990-2014**

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

	TJ	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Solid fuels & coal		3083.62 1.79%	2369.15 1.31%	3328.54 1.65%	3248.87 1.58%	3876.79 1.91%	3280.32 1.65%	3136.57 1.58%	2801.27 1.49%	2806.63 1.41%	2443.45 1.25%	2249.59 1.17%	2005.86 1.08%	2234.78 1.24%
Liquid fuels (incl. kerosene)		104261.62 60.42%	111789.85 61.74%	126709.57 62.91%	130884.49 63.82%	124308.27 61.24%	121227.03 60.92%	122120.30 61.40%	114419.02 60.75%	119823.60 59.99%	122367.06 62.53%	118245.32 61.76%	116275.75 62.65%	111686.26 61.98%
Natural gas (1)		49629.00 28.76%	50238.00 27.74%	55632.00 27.62%	54720.18 26.68%	57237.24 28.20%	53426.14 26.85%	50856.70 25.57%	51751.75 27.48%	55665.22 27.87%	48021.10 24.54%	48894.89 25.54%	41398.28 22.31%	39223.62 21.77%
Electricity		12952.77 7.51%	13931.02 7.69%	12698.58 6.30%	12323.47 6.01%	13490.64 6.65%	14981.85 7.53%	16412.67 8.25%	12987.43 6.90%	15290.40 7.66%	16677.00 8.52%	15567.70 8.13%	18791.88 10.13%	18634.29 10.34%
Heat		6.47 0.00%	9.85 0.01%	13.60 0.01%	17.53 0.01%	21.62 0.01%	28.95 0.01%	41.54 0.02%	62.85 0.03%	87.53 0.04%	122.76 0.06%	165.96 0.09%	220.21 0.12%	247.12 0.14%
Renewable energy sources & waste		2630.06 1.52%	2736.22 1.51%	3041.45 1.51%	3883.23 1.89%	4049.26 1.99%	6063.63 3.05%	6310.98 3.17%	6320.76 3.09%	6052.85 3.03%	6054.97 3.03%	6343.76 3.31%	6893.28 3.71%	8175.12 4.54%
<b>Total</b>		<b>172563.53</b>	<b>181074.09</b>	<b>201423.74</b>	<b>205077.78</b>	<b>202983.83</b>	<b>199007.92</b>	<b>198878.76</b>	<b>188343.07</b>	<b>199726.22</b>	<b>195686.34</b>	<b>191467.22</b>	<b>185585.25</b>	<b>180201.19</b>

**Figure 2-17 –Primary energy consumption: 1990-2014**



Source: STATEC, *Statistical Yearbook*, Table A.4200 (updated 24 February 2016):  
[http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=6139&IF\\_Language=fra&MainTheme=1&FldrName=4&RFPPath=54](http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=6139&IF_Language=fra&MainTheme=1&FldrName=4&RFPPath=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 (II).

**Final energy consumption** increased by 18% between 1990 and 2014. 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 1990-2014, 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 the biomass. Indeed, in 2014, 81.07% of the **final energy consumption** was covered by fossil fuels – 64.9% by liquid fuels including the important volume of road fuels as well as kerosene,<sup>56</sup> 14.8% by natural gas and 1.3% by coal. The remaining 15.4% of the consumption were either electricity (13.17%) and heat (2.25%) or renewable energy sources, including organic waste incineration with energy recovery, biogas, and biofuels (3.5%). 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 (-93.5%) 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 (+166.8%) 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 118% 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 2014 – and even first if “road fuel sales to non-residents” and kerosene are not considered.

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<sup>56</sup> 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.

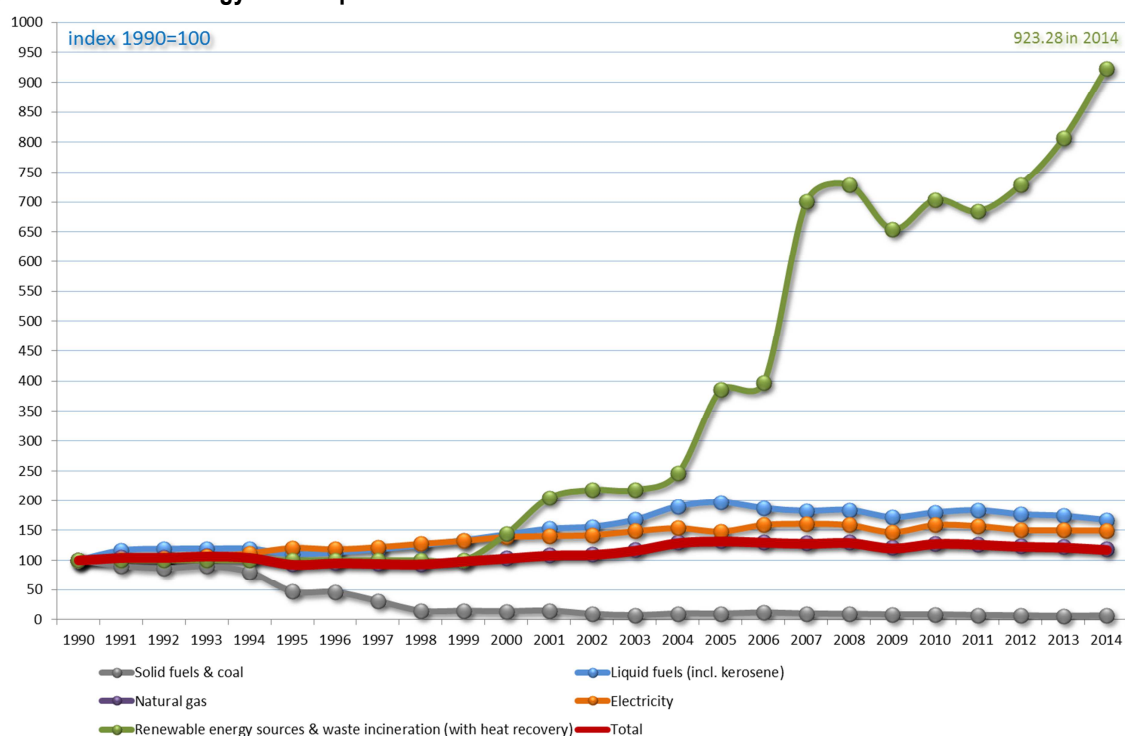
Table 2-8 – Final energy consumption: 1990-2014

	TJ	1990 (base year)	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Solid fuels & coal		34331.76 23.83%	30814.85 20.38%	29475.07 19.46%	30689.24 19.85%	27268.21 18.05%	16035.03 11.91%	15670.77 11.35%	10422.20 7.64%	4882.65 3.60%	4835.75 3.39%	4594.52 3.07%	4957.84 3.16%
Liquid fuels (incl. kerosene)		66193.31 45.95%	76911.52 50.87%	78669.97 51.93%	78837.44 51.00%	78753.71 52.14%	72682.85 53.99%	74734.38 54.13%	78046.98 57.20%	82554.07 60.90%	88082.74 61.67%	94644.90 63.26%	100723.34 64.28%
Natural gas (1)		19426.75 13.49%	20389.72 13.49%	21227.08 14.01%	22064.44 14.27%	21989.91 14.56%	23906.63 17.76%	26251.24 19.01%	27155.58 19.90%	27436.94 20.24%	28435.91 19.91%	28125.74 18.80%	27997.84 17.87%
Blast furnaces gas		8 457.34 5.87%	7 234.79 4.79%	6 196.46 4.09%	6 514.24 4.21%	5 503.55 3.64%	2 731.89 2.03%	2 511.66 1.82%	1 347.31 0.99%	NO NA	NO NA	NO NA	NO NA
Electricity		14988.74 10.41%	15198.08 10.05%	15281.82 10.09%	15826.10 10.24%	16747.20 11.09%	18045.11 13.40%	17710.16 12.83%	18254.45 13.38%	19091.81 14.08%	19835.80 13.89%	20790.21 13.90%	21033.19 13.42%
Heat (2)		NO NA	NO NA	NO NA	NO NA	125.60 0.08%	586.15 0.44%	547.21 0.40%	563.54 0.41%	949.98 0.70%	986.41 0.69%	537.71 0.36%	667.87 0.43%
Renewable energy sources & waste incineration (with heat recovery) (3)		644.77 0.45%	644.77 0.43%	644.77 0.43%	644.77 0.42%	644.77 0.43%	644.77 0.48%	644.77 0.47%	644.77 0.47%	644.77 0.48%	644.77 0.45%	929.70 0.62%	1321.31 0.84%
<b>Total</b>		<b>144042.67</b>	<b>151193.72</b>	<b>151495.17</b>	<b>154576.24</b>	<b>151032.95</b>	<b>134632.42</b>	<b>138070.20</b>	<b>136434.83</b>	<b>135560.21</b>	<b>142821.38</b>	<b>149622.78</b>	<b>156701.39</b>

	TJ	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Solid fuels & coal		3083.62 1.95%	2369.15 1.41%	3328.54 1.78%	3248.87 1.70%	3876.79 2.06%	3280.32 1.77%	3136.57 1.68%	2801.27 1.61%	2806.63 1.52%	2443.45 1.34%	2249.59 1.27%	2005.86 1.14%	2234.78 1.31%
Liquid fuels (incl. kerosene)		103120.21 65.15%	110621.65 65.80%	125715.23 67.32%	130171.42 68.31%	123605.43 65.82%	120541.81 65.17%	121487.76 65.06%	113538.02 65.31%	118810.49 64.38%	121233.69 66.33%	116795.59 65.68%	114950.05 65.37%	110460.66 64.92%
Natural gas (1)		28258.28 17.85%	28673.98 17.02%	29942.32 16.04%	29338.04 15.39%	30622.60 16.31%	29822.71 16.12%	30616.00 16.39%	28658.82 16.49%	31411.99 17.02%	27916.40 15.27%	28262.17 15.89%	27789.82 15.80%	25257.38 14.84%
Blast furnaces gas		NO NA	NO NA	NO NA	NO NA	NO NA	NO NA	NO NA	NO NA	NO NA	NO NA	NO NA	NO NA	NO NA
Electricity		21260.54 13.43%	22252.42 13.21%	23007.38 12.32%	22149.43 11.62%	23806.48 12.68%	24097.50 13.03%	23750.44 12.72%	22004.89 12.66%	23777.46 12.88%	23502.59 12.86%	22570.79 12.69%	22432.42 12.76%	22418.30 13.17%
Heat (2)		1149.89 0.73%	2906.68 1.73%	3149.21 1.69%	3172.87 1.66%	3332.59 1.77%	2696.05 1.46%	3056.39 1.64%	2622.47 1.51%	3200.50 1.73%	3276.46 1.79%	3245.60 1.83%	3466.70 1.97%	3833.94 2.25%
Renewable energy sources & waste incineration (with heat recovery) (3)		1405.98 0.89%	1406.76 0.84%	1586.77 0.85%	2489.86 1.31%	2562.50 1.36%	4518.54 2.44%	4697.03 2.52%	4219.33 2.43%	4539.12 2.46%	4414.70 2.42%	4700.15 2.64%	5202.83 2.96%	5953.00 3.50%
<b>Total</b>		<b>158278.52</b>	<b>168430.63</b>	<b>186729.46</b>	<b>190570.48</b>	<b>187806.38</b>	<b>184956.93</b>	<b>186744.19</b>	<b>173844.80</b>	<b>184546.18</b>	<b>182787.29</b>	<b>177823.89</b>	<b>175847.67</b>	<b>170158.06</b>

Figure 2-18 – Final energy consumption: 1990-2014



Source: STATEC, *Statistical Yearbook*, Table A.4300 (updated 24 February 2016):  
[http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=6149&IF\\_Language=fra&MainTheme=1&FldrName=4&RFPPath=51](http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=6149&IF_Language=fra&MainTheme=1&FldrName=4&RFPPath=51)

Notes: (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 (II);  
 (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 (II).

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.<sup>57</sup> 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%).<sup>58</sup> There are plans for decoupling heat at a later stage (28 MWth) for remote heating of the new Belval-Ouest district project.<sup>59</sup> 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 in 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. To complement this analysis, an energy balance for electric power is provided (Table 2-9 & Figure 2-19).

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<sup>57</sup> Then Arcelor and now, ArcelorMittal.

<sup>58</sup> [http://www.twinerg.lu/en\\_index.html](http://www.twinerg.lu/en_index.html), "Environment" tab and <http://www.ilr.public.lu/gaz/documents/statistiques/rapport2011.pdf>, p. 29.

<sup>59</sup> <http://www.belval.lu/en/>.

**Table 2-9 – Energy balance for electric power: 1990-2014**

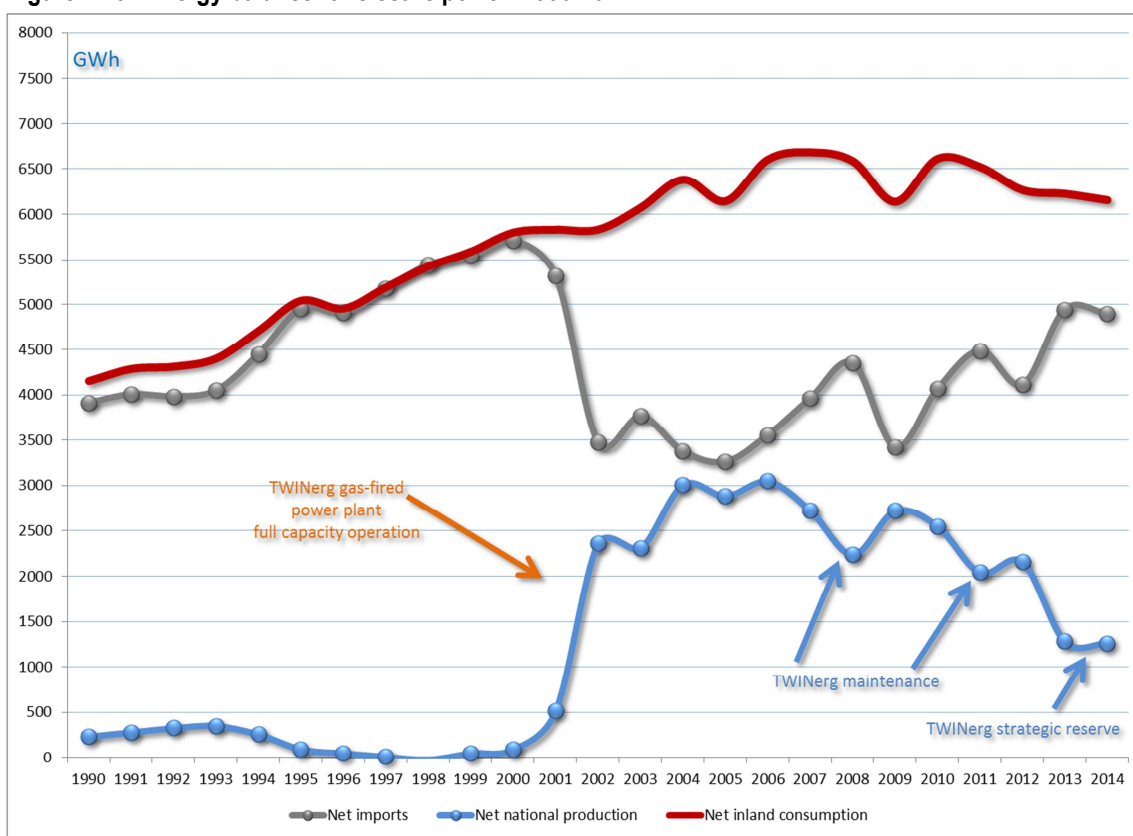
Imports	4665.46	4718.45	4523.56	4440.97	5015.24	5693.47	5712.33	6026.52	6366.60	6193.53	6445.38	6383.25
National production	626.24	676.37	662.49	669.79	622.07	527.70	482.06	430.92	409.91	390.16	449.58	928.65
cogeneration	NO	NO	NO	NO	30.00	99.84	122.35	124.83	198.03	205.15	227.96	321.41
thermic power stations	558.72	622.11	594.14	607.83	505.96	346.53	306.24	213.96	104.76	51.62	51.50	457.25
hydro-electricity	67.52	54.26	68.35	61.96	86.11	81.33	53.46	89.28	101.98	115.23	140.80	118.03
wind	NO	NO	NO	NO	NO	NO	NO	2.74	4.61	17.14	24.74	23.70
biomass & biogas	NO	NO	NO	NO	NO	NO	NO	0.12	0.52	1.01	4.54	8.20
gas from WWTPs	NO	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	NO
photovoltaic	NO	NO	NO	NO	NO	NO	NO	0.00	0.00	0.00	0.04	0.05
Total	5291.70	5394.82	5186.04	5110.76	5637.31	6221.17	6194.39	6457.44	6776.51	6583.68	6894.96	7311.90
Exports	754.92	715.17	542.95	394.41	565.57	744.15	808.06	846.96	924.12	654.97	736.85	1066.79
Conversion uses and losses	389.32	395.43	334.28	318.06	364.83	434.15	431.95	418.98	428.05	340.87	359.49	414.82
Net inland consumption	4147.45	4284.22	4308.82	4398.30	4706.91	5042.87	4954.38	5191.50	5424.34	5587.75	5798.62	5830.29
Total	5291.70	5394.82	5186.04	5110.76	5637.31	6221.17	6194.39	6457.44	6776.51	6583.68	6894.96	7311.90

Summary in GWh	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Net imports	3910.54	4003.28	3980.61	4046.57	4449.67	4949.32	4904.28	5179.56	5442.48	5538.56	5708.52	5316.46
Net national production (1)	236.91	280.95	328.21	351.73	257.24	93.55	50.11	11.94	-18.14	49.19	90.09	513.83
Net inland consumption	4147.45	4284.22	4308.82	4398.30	4706.91	5042.87	4954.38	5191.50	5424.34	5587.75	5798.62	5830.29
Net inland consumption in Mio. MJ (2)	14930.83	15423.21	15511.74	15833.88	16944.89	18154.34	17835.79	18689.40	19527.64	20115.89	20875.02	20989.06
Net inland consumption in 1000 tce	356.62	368.38	370.49	378.19	404.72	433.61	426.00	446.39	466.41	480.46	498.59	501.32

GWh	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Imports	6413.64	6562.18	6506.31	6391.61	6823.54	6846.58	6829.87	6022.47	7279.51	7096.00	6732.00	6852.00	6961.00
National production	2808.65	2784.36	3373.52	3336.93	3518.95	3190.23	2713.28	3142.69	3223.53	2648.00	2753.00	1845.00	1835.00
cogeneration	341.50	382.28	421.57	417.92	438.09	362.39	378.35	337.12	383.70	393.00	380.00	359.00	300.00
thermic power stations	2333.31	2285.48	2787.37	2736.60	2866.49	2598.86	2089.25	2571.43	2607.40	2049.00	2104.00	1157.00	1224.00
hydro-electricity	99.73	73.94	95.64	85.03	102.67	107.19	121.23	97.02	100.25	61.00	97.00	117.00	105.00
wind	24.73	26.17	39.40	52.45	57.99	64.29	60.59	63.47	55.08	64.00	75.00	81.00	71.00
biomass & biogas	9.30	15.13	20.34	27.24	32.60	36.59	38.51	47.22	50.40	49.00	52.00	49.00	53.00
gas from WWTPs	NO	NO	NO	NO	NO	NO	5.32	5.85	5.14	6.00	6.00	7.00	7.00
gas from landfill sites	NO	NO	NO	NO	NO	NO	NO	0.26	0.41	0.00	1.00	1.00	1.00
photovoltaic	0.08	1.36	9.20	17.70	21.11	20.90	20.03	20.32	21.15	26.00	38.00	74.00	74.00
Total	9222.29	9346.53	9879.83	9728.54	10342.49	10036.81	9543.15	9165.16	10503.04	9744.00	9485.00	8697.00	8796.00
Exports	2939.92	2799.41	3131.58	3131.31	3266.55	2886.84	2483.53	2604.45	3216.07	2614.00	2622.00	1908.00	2067.00
Conversion uses and losses	450.53	475.68	366.33	453.13	472.35	466.47	474.25	423.09	674.15	608.00	596.00	563.00	573.00
Net inland consumption	5831.84	6071.44	6381.92	6144.11	6603.59	6683.49	6585.37	6137.62	6612.82	6522.00	6267.00	6226.00	6156.00
Total	9222.29	9346.53	9879.83	9728.54	10342.49	10036.81	9543.15	9165.16	10503.04	9744.00	9485.00	8697.00	8796.00
Summary in GWh	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Net imports	3473.72	3762.77	3374.73	3260.30	3556.99	3959.74	4346.34	3418.02	4063.44	4482.00	4110.00	4944.00	4894.00
Net national production (1)	2358.12	2308.67	3007.19	2883.81	3046.60	2723.76	2239.03	2719.59	2549.38	2040.00	2157.00	1282.00	1262.00
Net inland consumption	5831.84	6071.44	6381.92	6144.11	6603.59	6683.49	6585.37	6137.62	6612.82	6522.00	6267.00	6226.00	6156.00
Net inland consumption in Mio. MJ (2)	20994.63	21857.19	22974.91	22118.79	23772.92	24060.58	23707.33	22095.41	23806.15	23479.20	22561.20	22413.60	22161.60
Net inland consumption in 1000 tce	501.45	522.05	548.75	528.30	567.81	574.68	566.24	527.74	568.60	560.79	538.87	535.34	529.32



**Figure 2-19 –Energy balance for electric power: 1990-2014**



**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.  
 (3) Provisional data for 2013 relates to gross national production, cogeneration, conversion process uses and losses, net inland consumption, and net national production.

## 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 is 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”.*

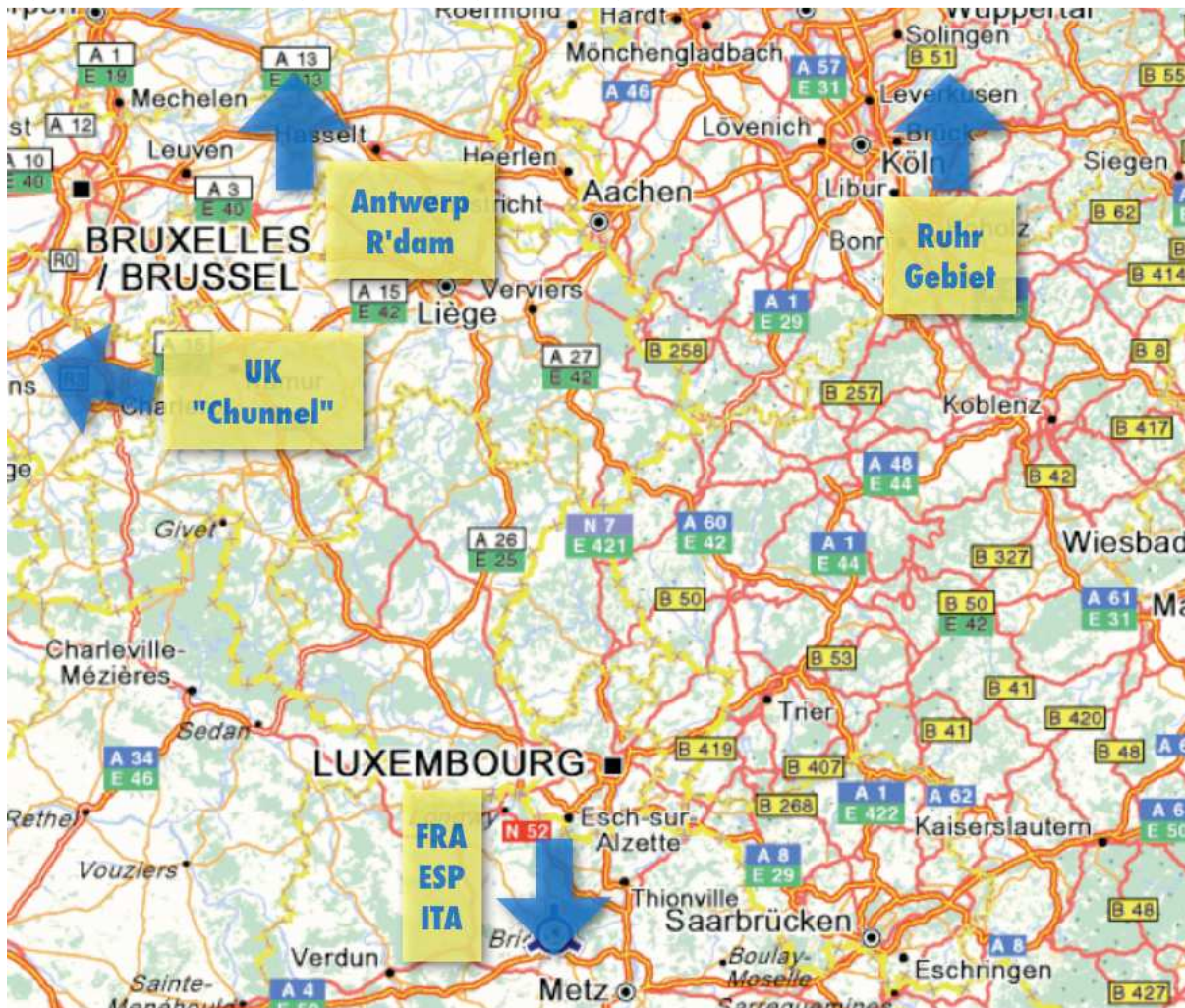
#### **2.1.6.2 Effects on GHG emissions: an untypical situation**

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 2014, some 6.04 Mio. t CO<sub>2</sub>e were produced by the road transportation sector and out of these, 4.5 Mio. t CO<sub>2</sub>e, corresponding to 74.9%, was the result of road fuels bought by non-residents and were, consequently, merely emitted abroad. That last amount represented around 42.1% of the total 2014 GHG emissions for Luxembourg (excluding LULUCF) while the whole CRF sub-category 1A3b accounted for 56.1% for of the total 2014 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: +79.8% and +152.35%

respectively.<sup>60</sup> 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 661 passenger cars per 1000 inhabitants between 1990 and 2014, *i.e.* the highest rate within the EU<sup>61</sup>). 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**

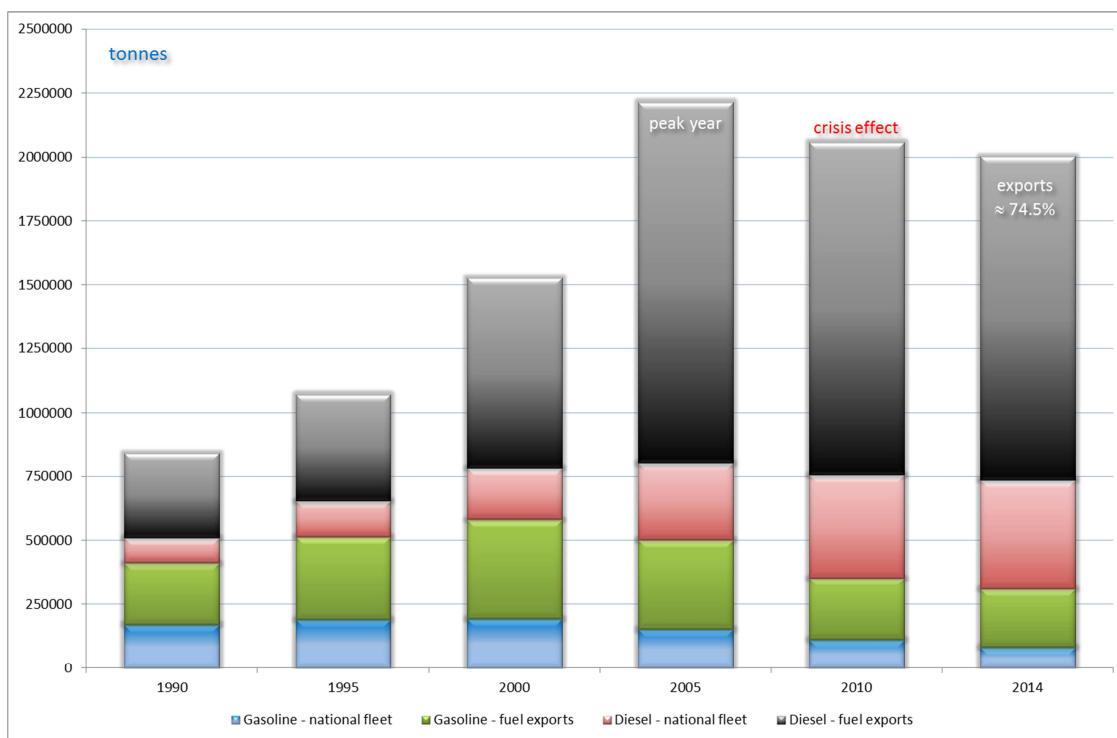


Source: ViaMichelin.

<sup>60</sup> 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<sub>2</sub> emissions from biomass which is not counted here.

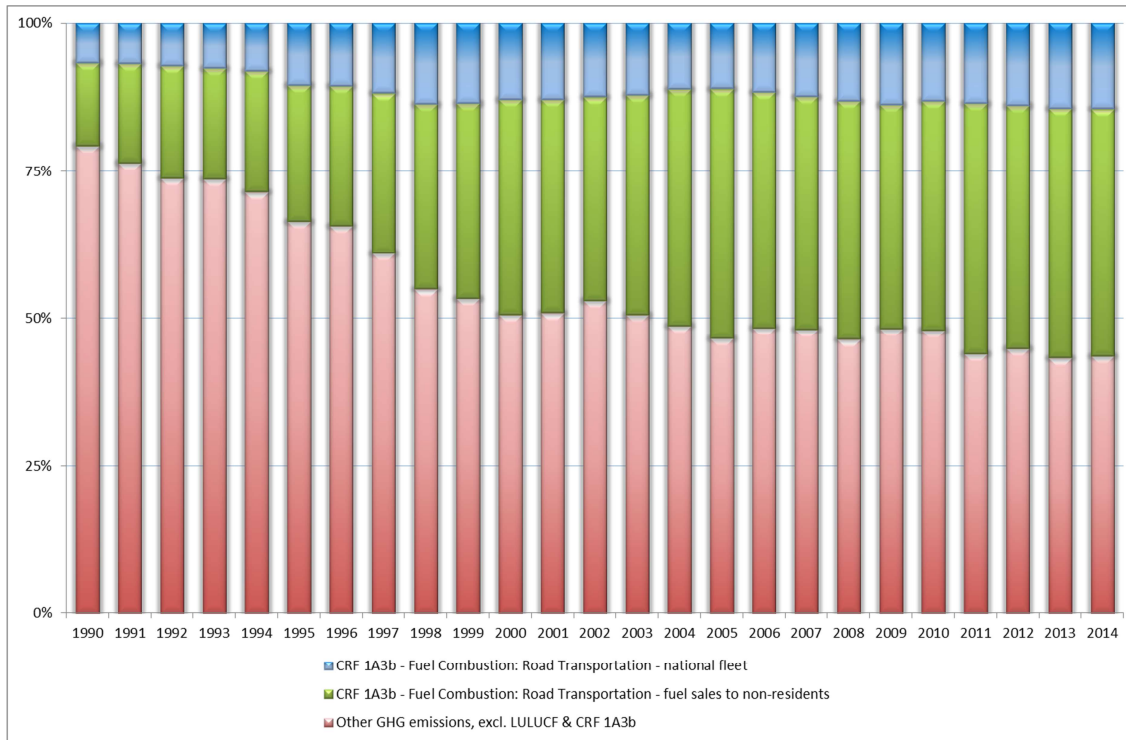
<sup>61</sup> Data extracted from European Commission (DG MOVE), *EU Transport in figures – statistical pocketbook 2015*, p.84: <http://ec.europa.eu/transport/facts-fundings/statistics/doc/2015/pocketbook2015.pdf>.

**Figure 2-21 – Road blended fuel sales: 1990-2014 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): 1990-2014**



Source: Submission 2016v1.1.

Note: CO<sub>2</sub> 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<sub>2</sub> emissions*” adopted in May 2013,<sup>62</sup> 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.<sup>63</sup> 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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<sup>62</sup> [http://www.environnement.public.lu/actualites/2013/05/plan\\_action\\_climat/index.html](http://www.environnement.public.lu/actualites/2013/05/plan_action_climat/index.html).

<sup>63</sup> For instance, by 2015 two major changes will impact 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 electromobility 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).

These last years, 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<sub>2</sub>e 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 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. 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 operation of the TWINerg power plant in 2008 and 2011 demonstrates.

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)<sup>64</sup> – total emissions from industry and electricity generation – *i.e.* largely the sectors covered by the EU-ETS – decreased to just 1.09 Mio. t CO<sub>2</sub>e in 2014 – or 10% of total GHG emissions (excluding LULUCF) – coming from slightly more than 6.3 Mio. t CO<sub>2</sub>e in 1990 – or about 49% of total GHG emissions (excluding LULUCF).<sup>65</sup>

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) 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<sub>2</sub>e in the GHG balance.<sup>66</sup> 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<sub>2</sub> 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.<sup>67</sup> 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**

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

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<sup>64</sup> Sum of CRF sub-categories 1A2a and 2C1. This percentage is 3.47% for 2014.

<sup>65</sup> 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<sub>2</sub>e) in 1998.

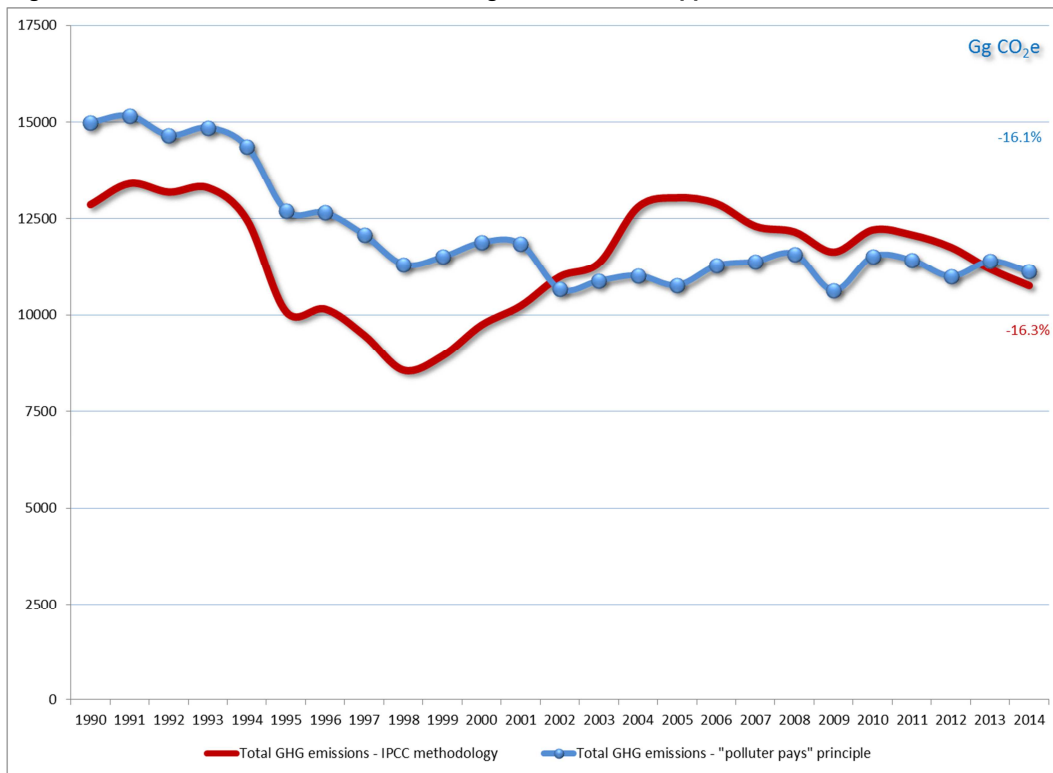
<sup>66</sup> 1 Mio. t CO<sub>2</sub>e for the TWINerg and 0.2 Mio. t CO<sub>2</sub>e for CHP installations.

<sup>67</sup> See the second *Action Plan for Reducing CO<sub>2</sub> Emissions* ([http://www.environnement.public.lu/actualites/2013/05/plan\\_action\\_climat/index.html](http://www.environnement.public.lu/actualites/2013/05/plan_action_climat/index.html)).

Now, if the “polluter pays” principle is used as a yardstick, Luxembourg's assessment reveals that GHG emissions according to the IPCC Guidelines are about 2.4 Mio. t CO<sub>2</sub>e different for 2014 (Figure 2-23).<sup>68</sup>

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:<sup>69</sup> it has been estimated that electricity net imports – with, nowadays, an average emission factors of 0.75 (kt CO<sub>2</sub> per GWh) – have fallen by more than 1 200 GWh since 2001 – the last year before the TWINerg power plant operates at full capacity – and have been replaced by national electricity generation with a current average emission factor of 0.41 (kt CO<sub>2</sub> per GWh).

**Figure 2-23 – Total GHG emissions, excluding LULUCF – two approaches: 1990-2014**



**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*

<sup>68</sup> After having reached a “surplus” of 1.8 Mio. t CO<sub>2</sub>e in 2005.

<sup>69</sup> GEMIS stands for *Global Emission Model for Integrated Systems*: <http://www.iinas.org/gemis-de.html>.



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 highly efficient national production plants which have just been constructed. In reality, they will replace the imported electricity which does not appear in 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.

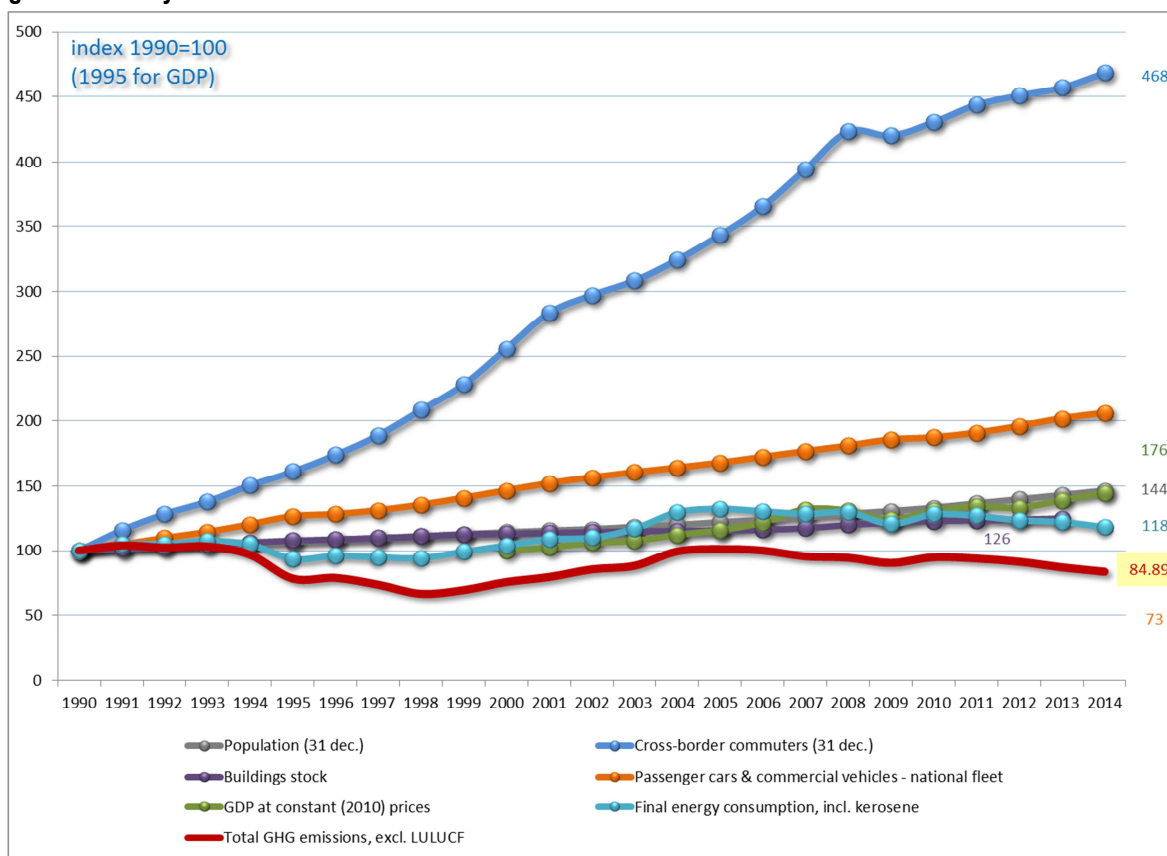
### 2.1.8 National circumstances: overview

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

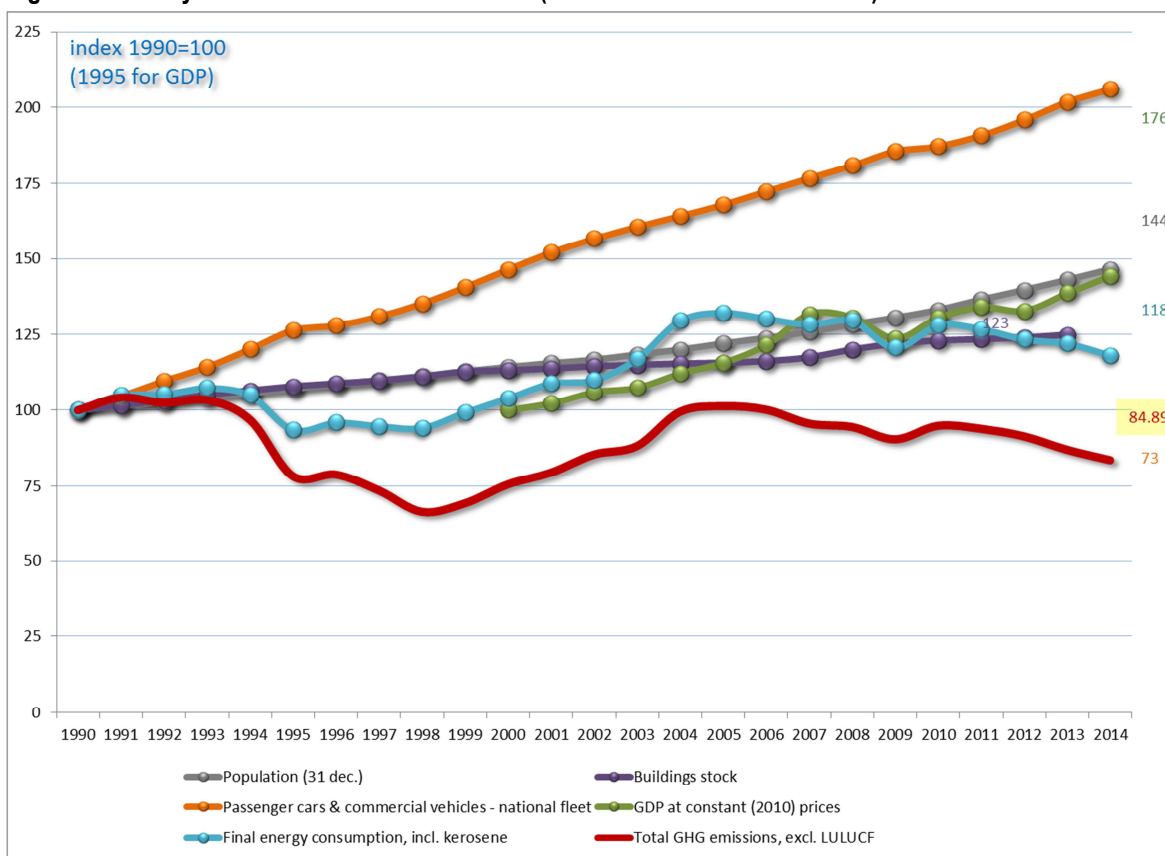
- a country characterized by both **high demographic** and **high economic growth** in a stagnating region, hence an **attractive economic destination**;
- **strong population growth** due to immigration and that is expected to go on;
- **even stronger cross-border commuters growth** that is expected 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.

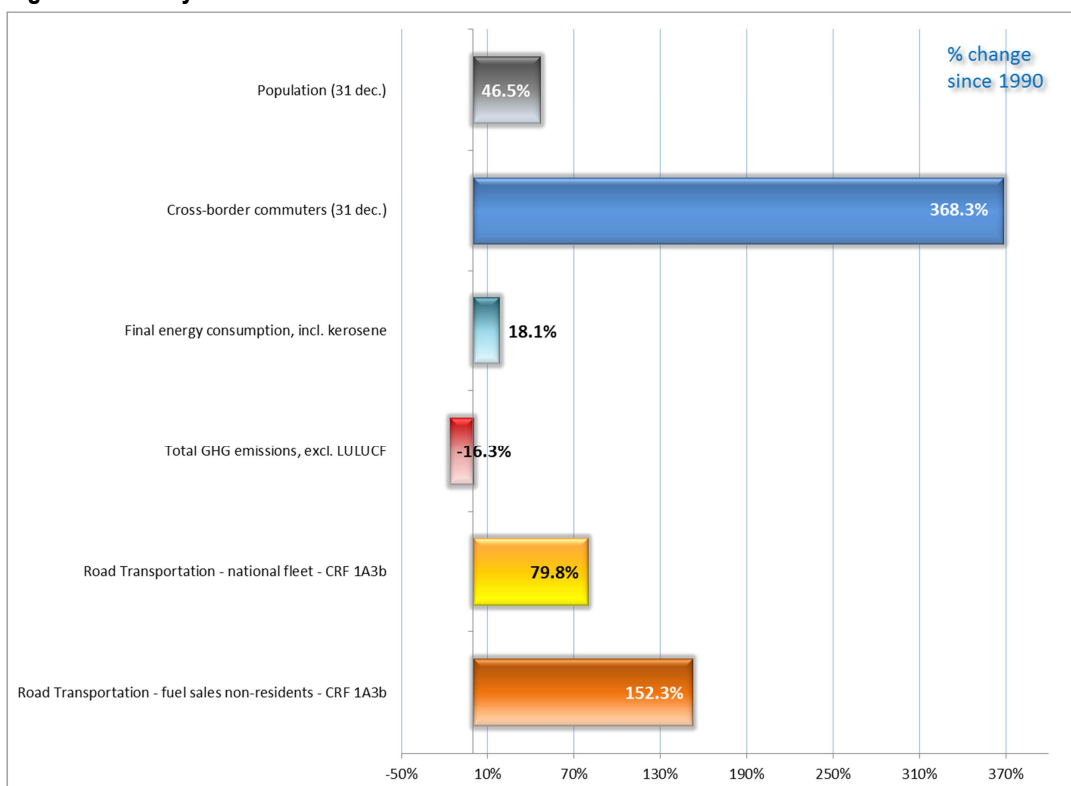
Figure 2-24 – Key variables trends – 1: 1990-2014



**Figure 2-25 – Key variables trends – 1: 1990-2014 (excl. cross-border commuters)**



**Figure 2-26 – Key variables trends – 2: 1990 & 2014**



**Sources:** Population: STATEC, *Statistical Yearbook*, Table B.1100 (updated 21 March 2016).  
[http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=383&IF\\_Language=fra&MainTheme=2&FldrName=1](http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=383&IF_Language=fra&MainTheme=2&FldrName=1)  
 Commuters: STATEC, *Statistical Yearbook*, Table B.3107 (updated 25 October 2015).  
[http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=494&IF\\_Language=fra&MainTheme=2&FldrName=3&RFPPath=92](http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=494&IF_Language=fra&MainTheme=2&FldrName=3&RFPPath=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=1368&IF\\_Language=fra&MainTheme=4&FldrName=4&RFPPath=35](http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=1368&IF_Language=fra&MainTheme=4&FldrName=4&RFPPath=35)  
<http://www.statistiques.public.lu/stat/tableviewer/document.aspx?ReportId=8624>  
 Cars & vehicles: STATEC, *Statistical Yearbook*, Table D.6102 (updated 13 January 2016).  
[http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=7066&IF\\_Language=fra&MainTheme=4&FldrName=6&RFPPath=7611](http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=7066&IF_Language=fra&MainTheme=4&FldrName=6&RFPPath=7611)  
 GDP: STATEC, *Statistical Yearbook*, Table E.2101 (updated 13 January 2016).  
[http://www.statistiques.public.lu/stat/TableViewer/document.aspx?ReportId=1497&IF\\_Language=fra&MainTheme=5&FldrName=2](http://www.statistiques.public.lu/stat/TableViewer/document.aspx?ReportId=1497&IF_Language=fra&MainTheme=5&FldrName=2)  
 Energy: STATEC, *Statistical Yearbook*, Table A.4300 (updated 19 November 2015).  
[http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=6149&IF\\_Language=fra&MainTheme=1&FldrName=4&RFPPath=51](http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=6149&IF_Language=fra&MainTheme=1&FldrName=4&RFPPath=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 2<sup>nd</sup> commitment period EU Member States aim to reduce GHG emissions by 20% with regard to the reference year 1990.

In 2014, carbon dioxide was the main source of GHG in Luxembourg. This source counted for 90.8% of the total GHG emissions calculated in CO<sub>2</sub>e – total excluding LULUCF.<sup>70</sup> The second source of GHG was methane with 5.5% of the total GHG emissions. Nitrous oxide was the third source with 2.9%. Fluorinated gases only accounted for 0.72% of the total GHG emissions, with hydrofluorocarbons representing 0.6% of the total GHG emissions and sulphur hexafluoride representing 0.08% of the total GHG emissions.

In 2014, total GHG emissions amounted to 10.7 Mio. t CO<sub>2</sub>e, 16.3% below their level in 1990 and 11.1% below the level retained for the base year under the Kyoto Protocol.<sup>71</sup> As Figure 2-27 shows, several phases can clearly be distinguished over the period 1990 to 2014:

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

<sup>70</sup> 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.

<sup>71</sup> The level of emissions considered for the base year is 12.029 Mio. t CO<sub>2</sub>e. The base year for CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O 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<sub>2</sub>e 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 last years, **the financial and economic crisis and its aftermaths** also played a part.

Table 2-10 – Luxembourg's GHG emissions and removals – overview by main gases and CRF Sectors: 1990-2014

Gg (1000 t) CO <sub>2</sub> equivalent	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
CO <sub>2</sub> emissions, incl. net CO <sub>2</sub> from LULUCF (1)	12009.02	12257.56	11710.98	11738.37	11114.00	8606.19	8628.15	7860.84	7064.81	7334.42	8112.70	8612.88	9368.20	9781.05	11203.90	11507.21	11450.61	10932.90	10762.43	10266.95	11137.73	10901.49	10516.22	9763.63	9366.66
CO <sub>2</sub> emissions, excl. net CO <sub>2</sub> from LULUCF	11961.50	12487.28	12269.88	12392.33	11578.79	9174.05	9236.43	8551.85	7640.24	8007.56	8819.12	9331.52	10088.77	10464.78	11891.92	12150.18	12012.04	11414.96	11258.43	10740.17	11294.32	11179.89	10882.32	10305.28	9829.93
CH <sub>4</sub> (2) emissions, incl. net CH <sub>4</sub> from LULUCF (1)	619.80	626.98	616.94	615.90	597.71	610.49	616.39	613.87	609.06	612.21	604.65	604.11	601.27	587.29	581.06	577.28	571.85	581.27	588.27	588.39	597.34	571.20	559.23	563.36	570.12
CH <sub>4</sub> (2) emissions, excl. net CH <sub>4</sub> from LULUCF	619.80	626.98	616.94	615.90	597.71	610.49	616.39	613.87	609.06	612.21	604.65	604.11	601.27	587.29	581.06	577.28	571.85	581.27	588.27	588.39	597.34	571.20	559.23	563.36	570.12
N <sub>2</sub> O (3) emissions, incl. net N <sub>2</sub> O from LULUCF (1)	293.39	306.03	295.62	289.82	287.75	290.01	291.17	291.55	294.95	292.10	292.52	278.89	282.50	277.48	296.62	278.43	272.62	269.80	271.24	268.99	273.96	281.28	268.30	272.46	298.84
N <sub>2</sub> O (3) emissions, excl. net N <sub>2</sub> O from LULUCF	288.77	301.41	291.20	285.21	283.13	285.39	286.55	286.93	290.33	287.48	287.95	274.38	278.04	273.07	292.26	274.12	267.76	265.60	267.23	265.18	270.34	277.86	265.07	269.44	296.01
HFCs (4)	0.00	0.00	13.68	14.70	15.98	17.90	19.63	22.05	24.45	26.25	28.98	32.85	35.65	37.93	39.99	38.99	41.88	46.46	48.81	49.67	52.33	55.19	57.53	61.17	66.08
PFCS (4)	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
SF <sub>6</sub> (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	3.73	4.28	4.85	5.27	5.69	6.10	6.49	6.87	7.31	7.68	8.05	8.23
1. Energy	10411.19	11023.26	10880.79	11026.95	10306.93	8260.47	8383.56	7810.85	7060.30	7387.73	8177.38	8753.33	9510.65	9953.48	11330.11	11607.81	11416.04	10820.78	10724.94	10271.69	10817.32	10680.15	10445.09	9887.16	9403.04
2. Industrial Processes	1648.46	1569.57	1511.54	1488.78	1396.74	1037.03	982.46	874.91	716.82	754.93	782.33	729.01	748.76	697.85	755.79	727.43	782.97	780.10	720.22	652.70	672.53	690.52	631.40	609.68	645.78
3. Agriculture	715.22	725.73	701.91	695.02	677.13	698.52	704.81	701.18	699.73	705.71	696.35	682.24	668.36	634.70	648.36	637.12	628.56	642.69	656.65	660.21	669.54	663.39	643.96	659.66	671.93
4. LULUCF	52.13	-225.11	-554.29	-649.35	-460.17	-563.24	-603.66	-686.40	-570.82	-668.53	-701.85	-714.13	-716.11	-679.32	-683.66	-638.66	-557.18	-477.85	-491.99	-469.41	-152.97	-274.98	-362.88	-538.62	-460.44
5. Waste	96.08	98.10	98.54	98.58	96.10	93.22	89.72	89.45	88.97	86.95	86.57	80.82	79.11	80.79	75.26	73.07	71.22	70.39	67.03	65.31	61.81	57.39	51.40	50.79	49.83
6. Other	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 including LULUCF	12923.08	13191.54	12638.49	12659.98	12016.74	9525.99	9556.90	8790.00	7995.01	8266.80	9040.78	9531.28	10290.77	10687.49	12125.85	12406.77	12341.62	11836.12	11676.85	11180.50	12068.22	11816.47	11408.96	10668.68	10310.14
Total GHG excluding LULUCF	12870.95	13416.64	13192.78	13309.33	12476.91	10089.23	10160.56	9476.40	8565.82	8935.33	9742.63	10245.40	11006.87	11366.81	12809.52	13045.43	12898.80	12313.97	12168.84	11649.91	12221.20	12091.45	11771.84	11207.30	10770.58

Source: Environment Agency and MDDI-DEV.

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

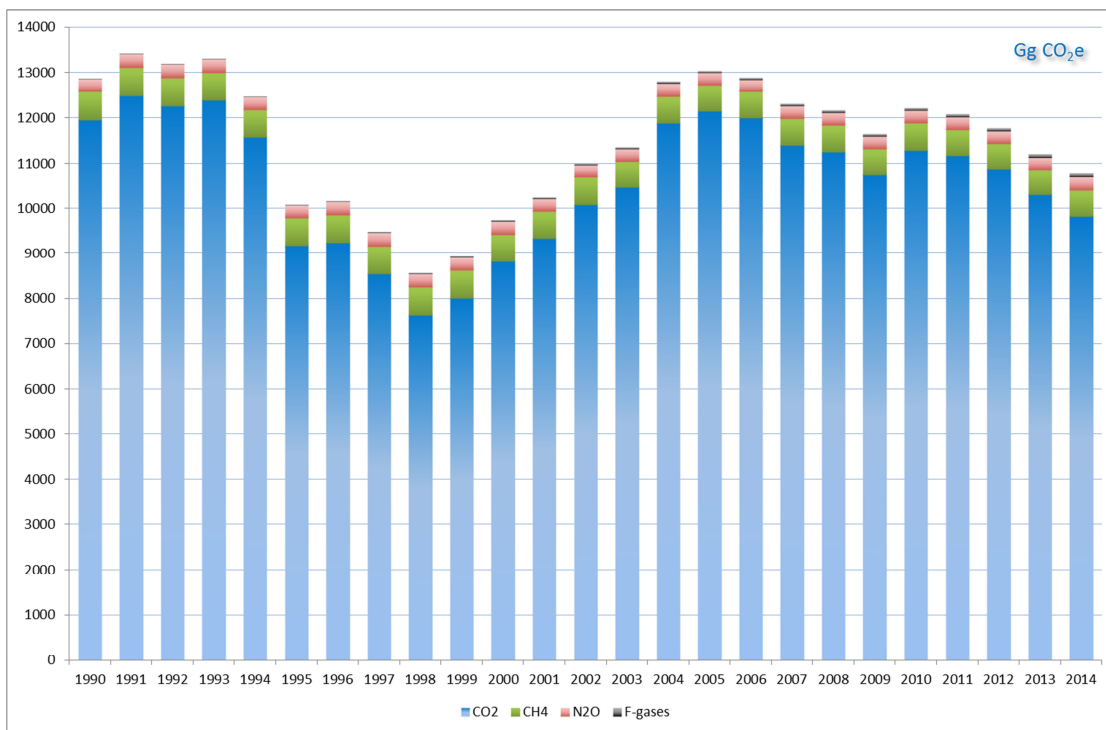
(2) The methane emissions are converted in CO<sub>2</sub> equivalents by multiplying the emissions by 25, i.e. the global warming potential (GWP) value for methane based on the effects of GHG over a 100-year time horizon.

(3) The nitrous oxide emissions are converted in CO<sub>2</sub> 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.

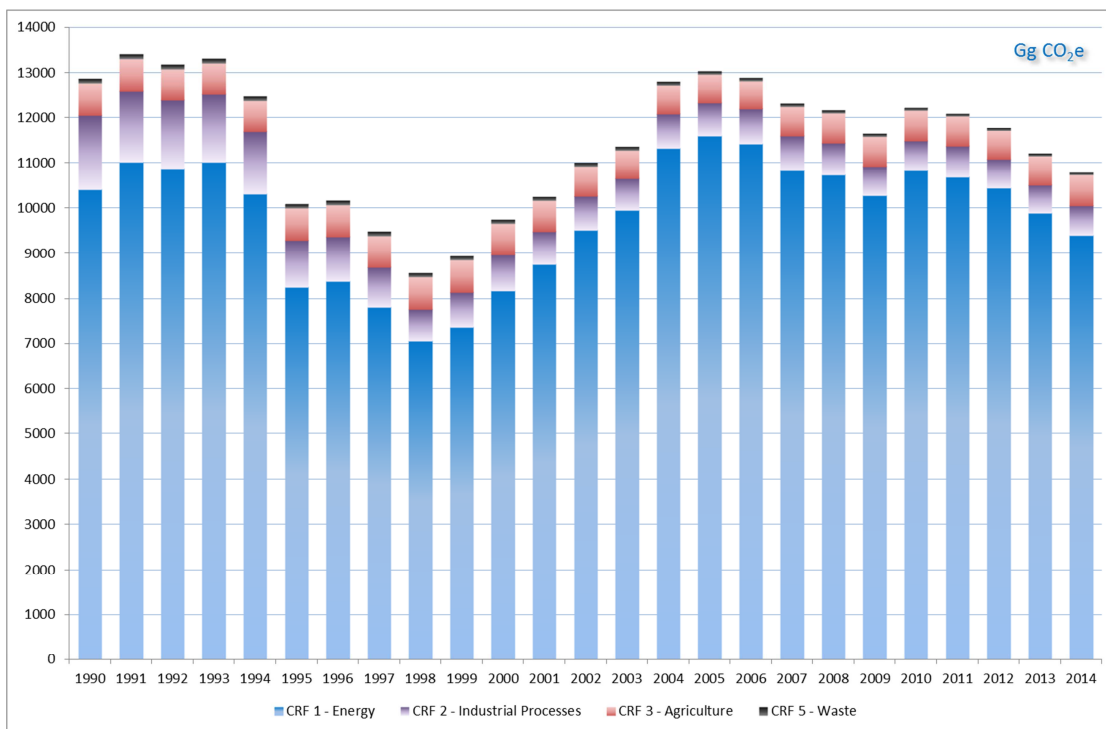
(4) The F-gases are those not covered by the Montreal Protocol, i.e. the HFCs, PFCs and SF<sub>6</sub> expressed in CO<sub>2</sub> equivalents using the global warming potential (GWP) values based on the effects of GHG over a 100-year time horizon.

**Figure 2-27 – Luxembourg's GHG emissions (excl. LULUCF) – absolute values: 1990-2014**

GHG



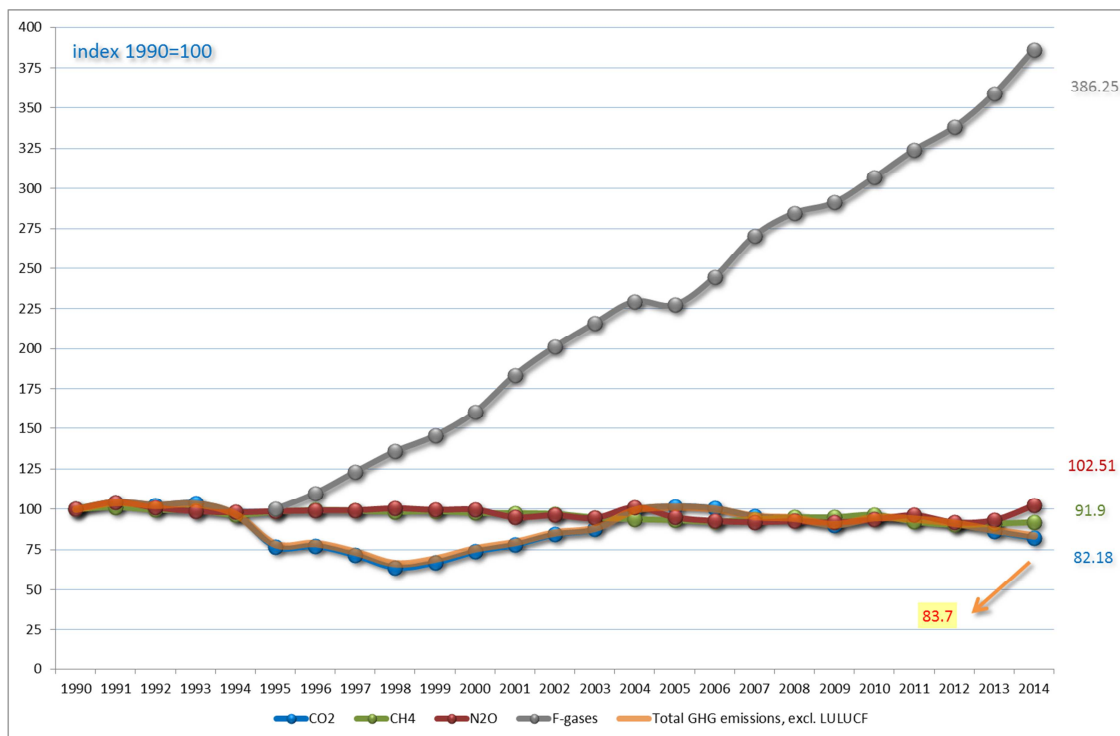
CRF Sectors



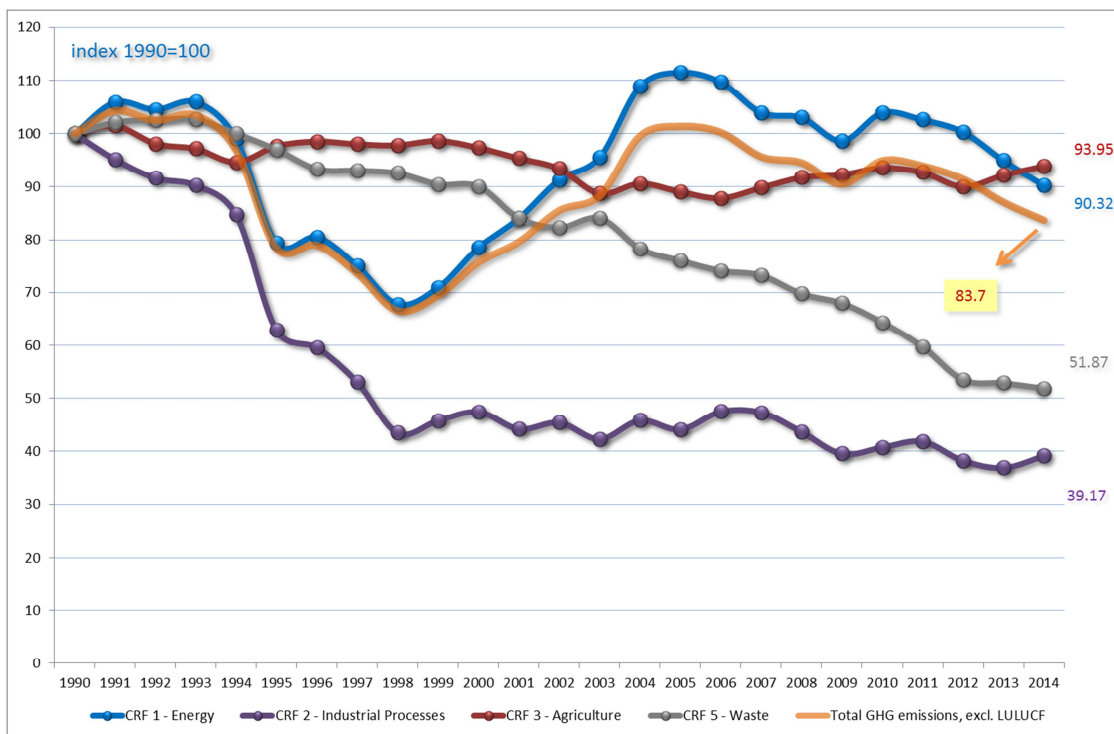
Sources: Environment Agency and MDDI-DEV.

**Figure 2-28 – Luxembourg's GHG emissions (excl. LULUCF) – indexes: 1990-2014**

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, 2011 and 2012 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 8).

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 7.7 Mio. t in 1990, CO<sub>2</sub>e emissions from industrial processes and fuel combustion in industry accounted for 61.1% of total GHG emissions. They could eventually be reduced to 1.68 Mio. t in 1998 – *i.e.* 20.7% 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 0.95 Mio. t CO<sub>2</sub>, *i.e.* around 8% of the total GHG emissions.

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 1990-2014 (and 2013-2014) were as follows:

- CO<sub>2</sub>: ..... -17.8% (-4.6%)
- CH<sub>4</sub>: ..... -8.0% (+1.2%)
- N<sub>2</sub>O: ..... +2.5% (+9.8%)
- F-gases: ..... +286.25% (+7.65%)

For carbon dioxide, the development between 1990 and 2014 hides a U-shape evolution over the period as well as important changes in the sources of CO<sub>2</sub> 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 declined over the period due to the conjunction of reduced methane emissions in waste and waste water management (-47.3%) that surpasses growing emissions in energy use (+18.03%). Methane emissions in agriculture decreased slightly (-1.88%).

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 17.22% over the period 1990-2014. This decrease has more than balanced the sharp increase – +59.8% – recorded for fossil fuels related emissions from combustion activities (mainly for the road transportation and the other sectors).

Finally, with regard to F-gases, HFC emissions were about 3.7 times higher in 2014 than in the base year (1995), whereas SF<sub>6</sub> emissions showed a 6.07-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: 1990-2014**

Gg (1000 t) CO <sub>2</sub> 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	
Main Emitting Source Categories																											
Public Electricity & Heat Production	1A1a	35.64 0.28%	36.41 0.27%	37.19 0.28%	35.38 0.27%	34.61 0.27%	33.06 0.33%	26.45 0.20%	38.78 0.47%	69.48 0.87%	81.03 0.91%	120.17 1.23%	282.26 2.76%	1029.32 9.35%	1037.21 9.12%	1261.58 9.80%	1243.98 9.94%	1308.02 10.14%	1184.14 9.62%	999.75 8.22%	1195.44 10.26%	1267.30 9.88%	1003.11 8.30%	1039.49 8.63%	686.10 6.12%	721.42 6.70%	
Iron & Steel (fuel combustion & processes)	1A2a + 2C1	6399.62 40.72%	6091.86 45.41%	5609.87 42.32%	5851.34 45.20%	4841.23 43.86%	2786.27 38.80%	2523.57 26.24%	1633.72 17.24%	451.44 5.27%	493.16 5.52%	487.44 5.30%	548.43 4.80%	530.66 4.60%	460.93 4.00%	561.24 4.38%	480.91 4.00%	532.45 4.58%	673.88 5.22%	662.73 5.38%	616.00 4.38%	510.66 4.74%	579.31 3.67%	444.32 3.76%	442.94 3.78%	431.38 3.85%	373.46 3.70%
Other Manufacturing Industries & Construction (fuel combustion & processes)	1A2b/c/d/ef/g + 2A	1515.56 9.71%	1584.89 12.27%	1671.67 12.42%	1534.07 11.52%	1732.36 13.88%	1565.34 15.52%	1631.00 16.05%	1662.67 17.50%	1646.51 19.22%	1762.61 19.73%	1691.47 17.36%	1710.17 16.69%	1670.46 15.18%	1648.64 14.50%	1743.45 14.61%	1715.30 13.61%	1692.95 13.15%	1572.51 12.77%	1477.04 12.00%	1364.75 11.03%	1428.00 11.59%	1518.20 12.34%	1333.57 13.12%	1244.93 13.09%	1234.50 13.47%	1234.50 14.41%
Road Transportation - national fleet	1A3b	863.46 6.71%	905.63 6.75%	939.16 7.12%	997.86 7.72%	1000.85 7.50%	1051.94 8.02%	1073.45 10.43%	1115.00 11.77%	1167.82 13.63%	1203.37 13.47%	1248.62 12.82%	1316.02 12.85%	1364.43 12.40%	1369.83 12.00%	1412.44 11.03%	1435.47 11.00%	1494.92 11.59%	1519.74 12.34%	1596.23 13.12%	1596.91 13.71%	1599.66 13.09%	1628.61 13.47%	1627.34 13.82%	1611.35 14.38%	1552.34 14.41%	
Road Transportation - fuel export	1A3b	1795.67 13.95%	2256.17 16.62%	2515.28 19.07%	2500.43 18.79%	2559.03 20.51%	2332.44 23.12%	2411.16 23.73%	2573.27 27.15%	2689.65 31.40%	2959.65 33.12%	3563.74 36.58%	3710.44 38.22%	3807.72 34.59%	4240.26 37.30%	5155.23 40.28%	5530.84 42.40%	5171.09 40.00%	4877.02 39.61%	4925.61 40.48%	4430.72 38.03%	4758.11 38.93%	5145.92 41.46%	4872.95 42.37%	4748.94 42.07%	4531.34 42.07%	
Residential Fuel Combustion	1A4b	674.09 5.24%	608.80 6.03%	742.90 5.63%	736.95 5.63%	701.33 5.45%	710.59 5.62%	736.95 7.09%	781.22 7.69%	756.91 7.99%	794.01 9.27%	709.84 7.94%	1076.16 11.00%	1165.12 11.37%	1108.80 10.07%	1152.01 10.13%	1232.81 9.62%	1207.47 9.26%	1195.49 9.27%	1155.82 9.39%	1168.92 9.77%	1175.55 10.09%	1154.05 9.44%	1057.33 8.74%	1076.01 9.14%	1069.51 9.54%	1001.63 9.35%
Commercial & Institutional Fuel Combustion	1A4a	640.15 4.97%	770.13 5.74%	710.59 5.30%	702.46 5.28%	676.83 5.42%	682.30 6.78%	761.54 7.50%	738.29 7.79%	772.36 9.02%	692.13 7.75%	598.16 6.14%	547.59 5.34%	541.66 4.92%	542.75 4.77%	521.00 4.07%	477.98 3.66%	466.73 3.62%	424.91 3.45%	433.76 3.58%	436.31 3.75%	540.71 4.42%	364.43 3.01%	471.66 4.01%	493.04 4.40%	395.24 3.67%	
Agriculture (fuel combustion, livestock, crops, soils)	1A4c+3	732.79 5.60%	746.79 5.57%	722.94 5.48%	712.55 5.30%	698.17 5.60%	716.06 7.10%	725.84 7.14%	725.80 7.68%	724.37 8.46%	737.64 8.26%	746.30 7.66%	738.65 7.21%	724.12 6.58%	693.88 6.10%	705.32 5.51%	694.56 5.32%	687.22 5.33%	702.03 5.70%	716.28 5.89%	726.78 6.24%	737.53 6.03%	717.94 5.93%	699.22 5.94%	719.63 6.42%	730.84 6.70%	
Other Source Categories																											
Other Transport	1A3a/c/d	29.12 0.23%	29.43 0.23%	29.45 0.22%	29.64 0.22%	28.84 0.23%	23.64 0.23%	26.19 0.26%	25.84 0.27%	25.68 0.30%	25.86 0.29%	25.39 0.26%	27.34 0.27%	24.43 0.22%	21.77 0.19%	17.54 0.14%	11.94 0.09%	9.24 0.07%	12.42 0.10%	14.08 0.12%	13.42 0.12%	14.41 0.12%	14.36 0.11%	13.18 0.10%	11.46 0.10%	13.04 0.12%	
Other Energy Sources (incl. lubricants reported under 1A3b)	1A5 + 1B2b	48.65 0.38%	49.38 0.37%	64.08 0.49%	59.53 0.45%	56.99 0.45%	41.13 0.45%	56.88 0.56%	61.83 0.62%	79.70 0.93%	127.20 1.42%	42.06 0.43%	57.42 0.56%	61.13 0.62%	51.50 0.45%	53.67 0.42%	52.80 0.40%	55.41 0.43%	51.84 0.42%	49.57 0.42%	50.11 0.41%	53.89 0.44%	46.72 0.39%	47.79 0.41%	40.69 0.36%	38.42 0.36%	
Solvent use and Other product manufacture	2D + 2G	40.10 0.31%	39.06 0.29%	37.42 0.28%	35.85 0.27%	34.58 0.28%	34.63 0.29%	34.11 0.34%	32.80 0.35%	31.38 0.37%	29.64 0.33%	27.56 0.28%	28.28 0.28%	29.38 0.27%	29.31 0.26%	29.98 0.23%	30.52 0.23%	30.68 0.24%	33.90 0.28%	34.21 0.29%	34.02 0.28%	38.76 0.32%	38.70 0.33%	40.83 0.36%	64.09 0.60%		
F-gases	2F	0.00 0.00%	0.00 0.00%	13.68 0.10%	14.70 0.11%	15.98 0.13%	17.90 0.19%	19.63 0.21%	22.05 0.23%	24.45 0.26%	26.25 0.29%	28.98 0.30%	32.85 0.32%	35.65 0.32%	37.93 0.33%	39.99 0.31%	38.99 0.30%	41.88 0.32%	46.46 0.38%	48.81 0.40%	49.67 0.42%	52.33 0.43%	55.19 0.46%	57.53 0.49%	58.60 0.52%	64.37 0.60%	
Municipal Waste Disposal on Land	5A	79.92 0.62%	81.95 0.61%	82.41 0.62%	81.37 0.61%	78.64 0.63%	73.21 0.72%	71.49 0.72%	69.08 0.75%	66.33 0.81%	64.63 0.75%	59.23 0.66%	57.84 0.58%	57.05 0.53%	51.10 0.40%	48.41 0.37%	45.84 0.34%	44.67 0.32%	42.22 0.30%	40.91 0.29%	37.05 0.30%	34.91 0.29%	30.80 0.26%	30.53 0.27%	28.67 0.27%	28.67 0.27%	
Waste Water Handling	5D	16.13 0.13%	16.11 0.12%	16.10 0.12%	16.18 0.12%	16.26 0.13%	16.03 0.16%	15.21 0.15%	15.17 0.16%	15.30 0.18%	15.35 0.17%	15.55 0.16%	15.73 0.15%	14.56 0.13%	14.56 0.12%	15.15 0.12%	15.27 0.12%	15.44 0.12%	15.72 0.13%	14.57 0.12%	14.34 0.12%	14.07 0.12%	14.28 0.10%	11.30 0.10%	11.31 0.11%	11.41 0.11%	
Composting	5B	0.00 NA	0.00 NA	0.00 NA	1.00 NA	1.16 NA	1.44 NA	1.26 NA	2.76 NA	4.58 NA	4.76 NA	6.38 NA	5.85 NA	6.59 NA	9.14 NA	8.87 NA	9.40 NA	9.82 NA	9.98 NA	10.23 NA	10.95 NA	10.67 NA	8.20 NA	9.28 NA	8.94 NA	9.55 NA	
<b>Total GHG excluding LULUCF</b>		<b>12870.91</b> 100.00%	<b>13416.61</b> 100.00%	<b>13192.74</b> 100.00%	<b>13309.29</b> 100.00%	<b>12476.87</b> 100.00%	<b>10089.20</b> 100.00%	<b>10160.53</b> 100.00%	<b>9476.36</b> 100.00%	<b>8565.80</b> 100.00%	<b>8935.31</b> 100.00%	<b>9742.61</b> 100.00%	<b>10245.39</b> 100.00%	<b>11006.85</b> 100.00%	<b>11366.79</b> 100.00%	<b>12809.49</b> 100.00%	<b>13045.33</b> 100.00%	<b>12898.70</b> 100.00%	<b>12313.88</b> 100.00%	<b>12168.76</b> 100.00%	<b>11649.83</b> 100.00%	<b>12221.11</b> 100.00%	<b>12091.37</b> 100.00%	<b>11771.77</b> 100.00%	<b>11207.24</b> 100.00%	<b>10770.52</b> 100.00%	
Netto Items																											
International Bunkers - Aviation		405.23 NA	423.55 NA	409.48 NA	404.98 NA	513.73 NA	582.36 NA	632.79 NA	757.03 NA	917.70 NA	1035.45 NA	986.91 NA	1067.43 NA	1156.48 NA	1204.77 NA	1310.90 NA	1332.01 NA	1246.59 NA	1339.90 NA	1348.76 NA	1292.14 NA	1321.14 NA	1240.67 NA	1144.73 NA	1150.47 NA	1248.79 NA	
International Bunkers - Marine		0.08 NA	0.09 NA	0.08 NA	0.11 NA	0.09 NA	0.09 NA	0.09 NA	0.09 NA	0.09 NA	0.09 NA	0.10 NA	0.11 NA	0.11 NA	0.11 NA	0.11 NA	0.15 NA	0.15 NA	0.13 NA	0.14 NA	0.11 NA	0.11 NA	0.13 NA	0.13 NA	0.11 NA	0.12 NA	
CO <sub>2</sub> Emissions from Biomass		159.05 NA	160.93 NA	163.73 NA	159.33 NA	157.46 NA	153.78 NA	135.56 NA	146.84 NA	139.67 NA	148.82 NA	149.63 NA	163.83 NA	163.75 NA	181.66 NA	200.80 NA	294.95 NA	301.06 NA	441.68 NA	456.67 NA	429.35 NA	446.59 NA	465.53 NA	453.91 NA	496.72 NA	570.64 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<sub>2</sub> 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<sub>2</sub> 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.

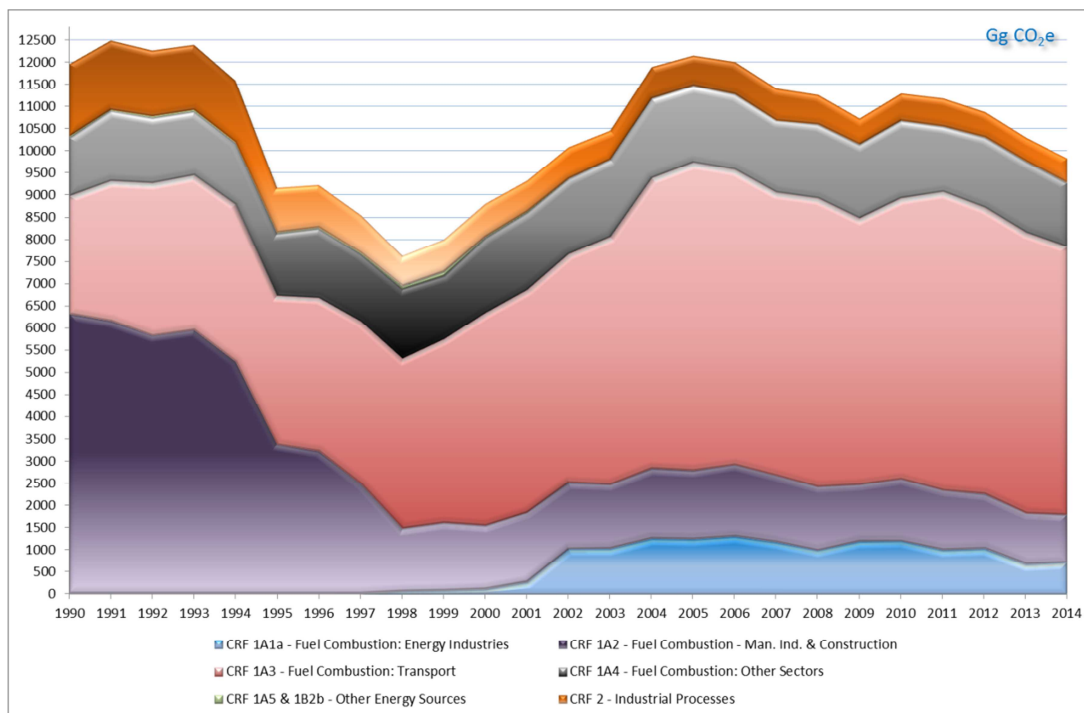
(4) The F-gases are those not covered by the Montreal Protocol, *i.e.* the HFCs, PFCs and SF<sub>6</sub> expressed in CO<sub>2</sub> equivalents using the global warming potential (GWP) values based on the effects of GHG over a 100-year time horizon.

**Table 2-12 – Luxembourg's GHG emissions and removals – details by main gases: 1990-2014**

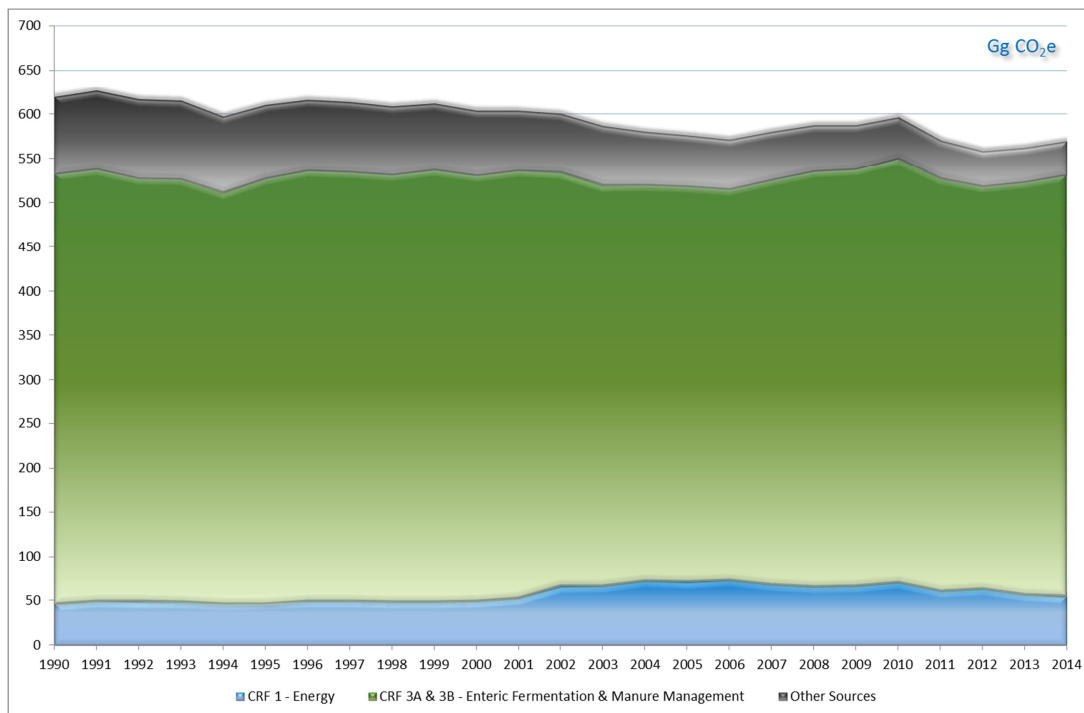
	Gg (1000 t) CO <sub>2</sub> equivalent		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	(base year)		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
<b>CO<sub>2</sub></b>	<b>11961.50</b>	<b>12487.28</b>	<b>12269.88</b>	<b>12392.33</b>	<b>11578.79</b>	<b>9174.05</b>	<b>9236.43</b>	<b>8551.85</b>	<b>7640.24</b>	<b>8007.56</b>	<b>8819.12</b>	<b>9331.52</b>	<b>10088.77</b>	<b>10464.78</b>	<b>11891.92</b>	<b>12150.18</b>	<b>12012.04</b>	<b>11414.96</b>	<b>11258.43</b>	<b>10740.17</b>	<b>11294.32</b>	<b>11179.89</b>	<b>10882.32</b>	<b>10305.28</b>	<b>9829.93</b>	<b>9829.93</b>	
	92.93%	93.07%	93.00%	93.11%	92.80%	90.93%	90.90%	90.24%	89.19%	89.62%	90.52%	91.08%	91.68%	92.08%	92.84%	93.14%	93.13%	92.70%	92.52%	92.19%	92.42%	92.46%	92.44%	91.95%	91.27%	91.27%	
of which																											
CRF 1 - Energy	10322.24	10926.56	10780.50	10926.40	10205.55	8162.48	8281.12	7705.85	6953.89	7285.54	8071.40	8640.83	9381.17	9810.88	11182.60	11466.96	11277.72	10688.81	10595.59	10144.25	10680.38	10550.40	10314.36	9761.99	9280.34	9280.34	
	86.20%	87.44%	87.72%	89.10%	88.10%	88.90%	81.50%	81.32%	81.18%	81.54%	82.85%	84.34%	85.23%	86.30%	87.30%	87.90%	87.43%	86.80%	87.08%	87.30%	87.20%	87.20%	87.20%	87.20%	87.20%	87.20%	
CRF 1A1 - Fuel Combustion from Energy Industries	33.29	34.01	34.73	33.04	32.32	30.87	24.76	36.77	67.01	78.19	117.37	279.33	1025.62	1033.38	1257.24	1239.93	1303.70	1179.86	995.52	1191.11	1203.27	999.04	1035.44	682.30	717.70	717.70	
	0.28%	0.25%	0.28%	0.25%	0.26%	0.31%	0.24%	0.39%	0.78%	0.88%	1.20%	2.73%	9.32%	9.08%	9.81%	9.50%	10.11%	9.58%	8.18%	10.22%	9.85%	8.26%	8.80%	6.09%	6.66%	6.66%	
CRF 1A2 - Fuel Combustion from Manuf. Industries & Construction	6287.64	6127.18	5800.53	5927.43	5207.86	3350.99	3208.90	2458.49	1419.07	1544.83	1440.66	1575.41	1496.91	1445.79	1586.49	1559.96	1629.40	1512.43	1438.73	1291.59	1404.80	1352.33	1229.98	1155.07	1079.88	1079.88	
	46.85%	45.67%	43.97%	44.54%	41.74%	33.22%	31.58%	25.94%	16.57%	17.29%	14.79%	15.38%	13.60%	12.72%	12.39%	11.98%	12.63%	12.28%	11.82%	11.09%	11.49%	10.49%	10.33%	10.33%	10.33%	10.33%	
CRF 1A3 - Fuel Combustion from Transport	2657.87	3155.68	3445.11	3498.30	3547.23	3368.66	3470.55	3673.16	3842.73	4147.97	4795.61	5012.76	5157.80	5593.71	6547.30	6942.54	6641.74	6373.47	6496.43	6001.40	6328.05	6738.39	6462.51	6320.41	6044.32	6044.32	
of which, "road fuel export(t)"	20.65%	23.52%	26.11%	26.21%	28.43%	33.39%	34.16%	38.76%	44.66%	46.42%	49.22%	48.63%	46.88%	49.21%	51.11%	53.22%	51.49%	51.76%	53.30%	51.51%	51.78%	55.73%	54.90%	56.40%	56.12%	56.12%	
	1795.67	2256.17	2515.28	2500.43	2559.03	2332.44	2411.16	2573.27	2689.65	2959.65	3563.74	3710.44	3807.72	4240.26	5155.23	5530.84	5171.09	4877.02	4925.61	4430.72	4758.11	5145.92	4872.95	4748.94	4531.34	4531.34	
	13.95%	16.82%	19.07%	18.79%	20.51%	23.12%	23.73%	27.15%	31.40%	33.12%	36.58%	36.22%	34.59%	37.30%	40.25%	42.40%	40.09%	39.61%	40.48%	38.03%	38.93%	42.56%	41.40%	42.37%	42.07%	42.07%	
CRF 1A4 - Fuel Combustion from Other Sectors	1316.90	1583.16	1458.87	1441.49	1384.54	1396.44	1548.80	1575.56	1420.50	1705.68	1749.24	1687.41	1734.80	1791.50	1724.45	1702.81	1622.98	1664.84	1660.08	1744.19	1460.58	1586.37	1604.16	1438.38	1438.38	1438.38	
	10.23%	11.80%	11.06%	10.83%	11.10%	13.84%	15.24%	15.88%	18.39%	17.51%	17.07%	15.33%	15.26%	13.99%	13.22%	13.20%	13.18%	13.68%	14.25%	14.27%	12.08%	13.48%	14.31%	13.35%	13.35%	13.35%	
CRF 1A5 & 1B2b - Other Energy Sources	26.51	26.51	41.23	36.12	33.56	15.49	28.08	32.59	49.49	94.01	12.05	24.04	13.37	3.13	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	0.21%	0.20%	0.31%	0.27%	0.27%	0.15%	0.28%	0.34%	0.58%	1.05%	0.12%	0.22%	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	1638.68	1560.01	1488.55	1464.98	1371.87	1010.45	954.32	844.54	684.33	720.90	745.82	688.40	704.70	651.09	706.90	679.31	731.27	723.07	659.98	591.84	609.76	624.60	562.90	537.48	543.78	543.78	
	12.72%	11.83%	11.28%	11.01%	11.01%	10.02%	9.39%	8.91%	7.39%	8.07%	7.88%	6.72%	6.40%	5.73%	5.52%	5.21%	5.87%	5.42%	5.08%	4.99%	5.17%	4.78%	4.80%	5.05%	5.05%	5.05%	
Other Sources (R)	30.32	29.50	28.11	26.76	25.68	25.96	25.59	24.47	23.34	21.86	20.04	20.52	20.97	20.49	21.09	21.40	20.85	23.32	24.27	23.03	23.57	28.04	27.73	26.46	26.46	26.46	
	0.24%	0.22%	0.21%	0.20%	0.21%	0.25%	0.26%	0.26%	0.27%	0.24%	0.21%	0.20%	0.19%	0.19%	0.16%	0.16%	0.16%	0.19%	0.20%	0.20%	0.20%	0.24%	0.24%	0.24%	0.24%	0.24%	
<b>CH<sub>4</sub> (t)</b>	<b>619.80</b>	<b>626.98</b>	<b>616.94</b>	<b>615.90</b>	<b>597.71</b>	<b>610.49</b>	<b>616.39</b>	<b>613.87</b>	<b>609.06</b>	<b>612.21</b>	<b>604.65</b>	<b>604.11</b>	<b>601.27</b>	<b>587.29</b>	<b>581.06</b>	<b>577.28</b>	<b>571.85</b>	<b>581.27</b>	<b>588.27</b>	<b>588.39</b>	<b>597.34</b>	<b>571.20</b>	<b>559.23</b>	<b>563.36</b>	<b>570.12</b>	<b>570.12</b>	
	4.82%	4.67%	4.68%	4.63%	4.79%	6.00%	6.07%	6.48%	7.11%	6.85%	6.21%	5.90%	5.46%	5.17%	4.54%	4.43%	4.43%	4.63%	4.83%	5.03%	4.72%	4.73%	5.03%	5.29%	5.29%	5.29%	
of which																											
CRF 1 - Energy	46.57	49.64	49.38	49.07	47.50	48.16	49.75	49.45	49.02	49.18	49.75	53.11	66.32	66.72	72.49	71.18	73.23	68.35	66.13	70.55	61.20	63.36	57.30	54.96	54.96	54.96	
	0.36%	0.37%	0.37%	0.37%	0.38%	0.48%	0.49%	0.52%	0.57%	0.55%	0.51%	0.52%	0.60%	0.59%	0.57%	0.59%	0.57%	0.56%	0.54%	0.57%	0.58%	0.51%	0.54%	0.51%	0.51%	0.51%	
CRF 3A+3B - Enteric Fermentation and Manure Management	486.01	488.26	478.21	478.13	464.32	479.39	486.53	485.38	482.92	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	476.87	476.87	476.87	
	3.78%	3.64%	3.62%	3.59%	3.72%	4.79%	4.79%	4.79%	4.79%	4.79%	4.79%	4.79%	4.79%	4.79%	4.79%	4.79%	4.79%	4.79%	4.79%	4.79%	4.79%	4.79%	4.79%	4.79%	4.79%	4.79%	
Other Sources (R)	87.22	89.07	89.34	88.70	85.89	82.94	80.12	77.47	74.05	73.63	67.77	66.76	67.12	60.94	58.38	56.09	54.90	52.29	50.17	46.96	43.82	40.28	39.67	38.28	38.28	38.28	
	0.68%	0.66%	0.68%	0.67%	0.69%	0.82%	0.79%	0.83%	0.80%	0.84%	0.76%	0.68%	0.67%	0.59%	0.48%	0.45%	0.43%	0.43%	0.43%	0.38%	0.36%	0.34%	0.35%	0.35%	0.35%	0.35%	
<b>N<sub>2</sub>O (t)</b>	<b>288.77</b>	<b>301.41</b>	<b>291.20</b>	<b>285.21</b>	<b>283.13</b>	<b>285.39</b>	<b>286.55</b>	<b>286.93</b>	<b>290.33</b>	<b>287.48</b>	<b>287.95</b>	<b>274.38</b>	<b>278.04</b>	<b>273.07</b>	<b>292.26</b>	<b>274.12</b>	<b>267.76</b>	<b>265.60</b>	<b>267.23</b>	<b>265.18</b>	<b>270.34</b>	<b>277.86</b>	<b>265.07</b>	<b>269.44</b>	<b>296.01</b>	<b>296.01</b>	
	2.24%	2.25%	2.21%	2.14%	2.27%	2.83%	2.82%	3.03%	3.39%	3.22%	2.96%	2.68%	2.53%	2.40%	2.28%	2.10%	2.08%	2.16%	2.20%	2.28%	2.21%	2.30%	2.25%	2.40%	2.75%	2.75%	
of which																											
CRF 1 - Energy	42.39	47.05	50.90	51.48	53.88	49.83	52.69	55.56	57.38	53.01	56.22	59.39	63.15	75.89	75.01	69.66	65.09	63.63	63.22	60.99	66.39	68.55	67.36	67.87	67.74	67.74	
	0.33%	0.35%	0.39%	0.39%	0.43%	0.49%	0.52%	0.59%	0.57%	0.59%	0.59%	0.59%	0.57%	0.67%	0.59%	0.53%	0.50%	0.52%	0.52%	0.52%	0.54%	0.57%	0.57%	0.57%	0.57%		
CRF 3D - Agricultural Soils	189.54	198.41	195.44	178.70	175.05	179.12	177.87	175.14	176.18	177.86	175.56	159.39	161.65	143.15	163.86	151.15	149.67	147.68	149.30	149.87	150.72	158.64	150.41	153.39	154.49	154.49	
	1.47%	1.48%	1.41%	1.34%	1.40%	1.78%	1.79%	1.69%	1.69%	1.80%	1.80%	1.50%	1.47%	1.28%	1.28%	1.16%	1.16%	1.20%	1.20%	1.20%	1.23%	1.31%	1.28%	1.37%	1.43%	1.43%	
Other Sources (R)	56.85	55.95	54.86	55.03	54.20	56.44	55.98	56.76	56.61	56.17	55.60	53.23	54.03	53.39	53.31	53.00	54.29	54.72	54.32	53.23	50.67	47.30	48.18	73.79	73.79	73.79	
	0.44%	0.42%	0.42%	0.41%	0.43%	0.56%	0.55%	0.59%	0.60%	0.63%	0.58%	0.54%	0.48%	0.48%	0.42%	0.41%	0.41%	0.44%	0.45%	0.47%	0.44%	0.40%	0.40%	0.43%	0.69%	0.69%	
<b>F-gases (t)</b>	<b>0.88</b>	<b>0.98</b>	<b>14.76</b>	<b>15.88</b>	<b>17.28</b>	<b>21.19</b>	<b>23.74</b>	<b>26.19</b>	<b>28.07</b>	<b>30.91</b>	<b>35.39</b>	<b>38.80</b>	<b>41.67</b>	<b>44.28</b>	<b>43.85</b>	<b>47.15</b>	<b>52.15</b>	<b>54.91</b>	<b>56.17</b>	<b>59.20</b>	<b>62.50</b>	<b>65.21</b>	<b>69.22</b>	<b>74.52</b>	<b>74.52</b>	<b>74.52</b>	
	0.01%	0.01%	0.11%	0.12%	0.14%	0.19%	0.21%	0.25%	0.31%	0.32%	0.35%	0.39%	0.41%	0.41%	0.39%	0.41%	0.41%	0.42%	0.45%	0.48%	0.48%	0.52%	0.55%	0.62%	0.69%	0.69%	
<b>Total GHG excluding LULUCF</b>	<b>12870.95</b>	<b>13416.64</b>	<b>13192.78</b>	<b>13309.33</b>	<b>12476.91</b>	<b>10089.23</b>	<b>10160.56</b>	<b>9476.40</b>	<b>8565.82</b>	<b>8935.33</b>	<b>9742.63</b>	<b>10245.40</b>	<b>11006.87</b>	<b>11366.81</b>	<b>12809.52</b>	<b>13045.43</b>	<b>12898.80</b>	<b>12313.97</b>	<b>12168.84</b>	<b>11649.91</b>	<b>12221.20</b>	<b>12091.45</b>					

**Figure 2-29 – Luxembourg's GHG emissions (excl. F-gases & LULUCF) – details by main gases:  
1990-2014**

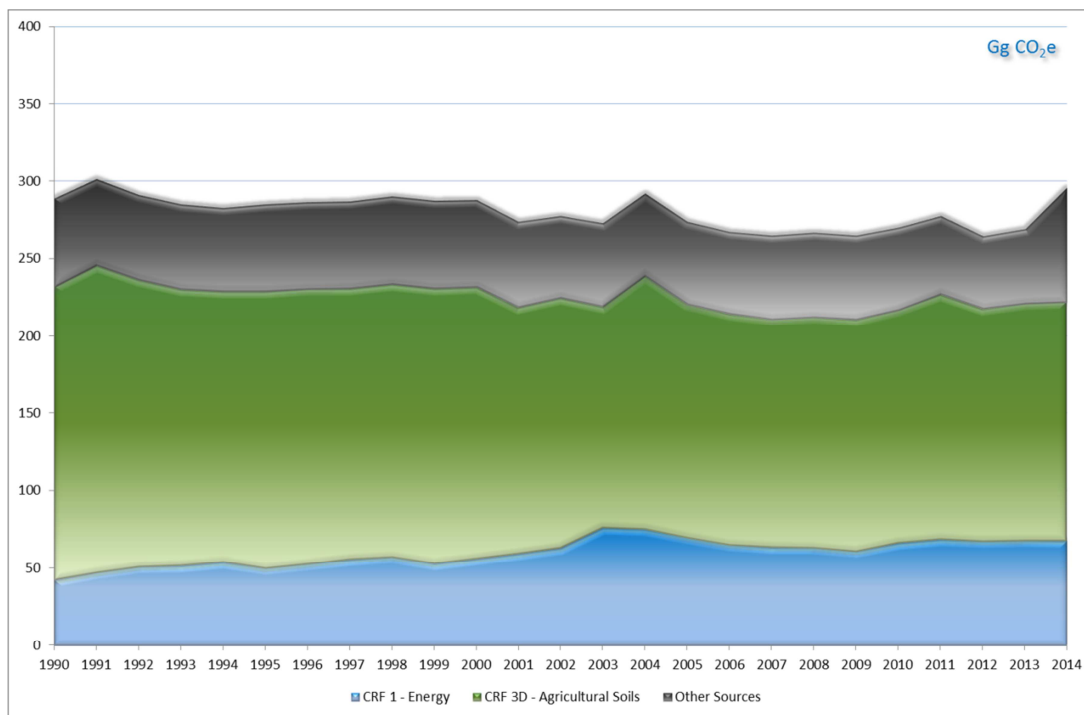
CO<sub>2</sub>



CH<sub>4</sub>



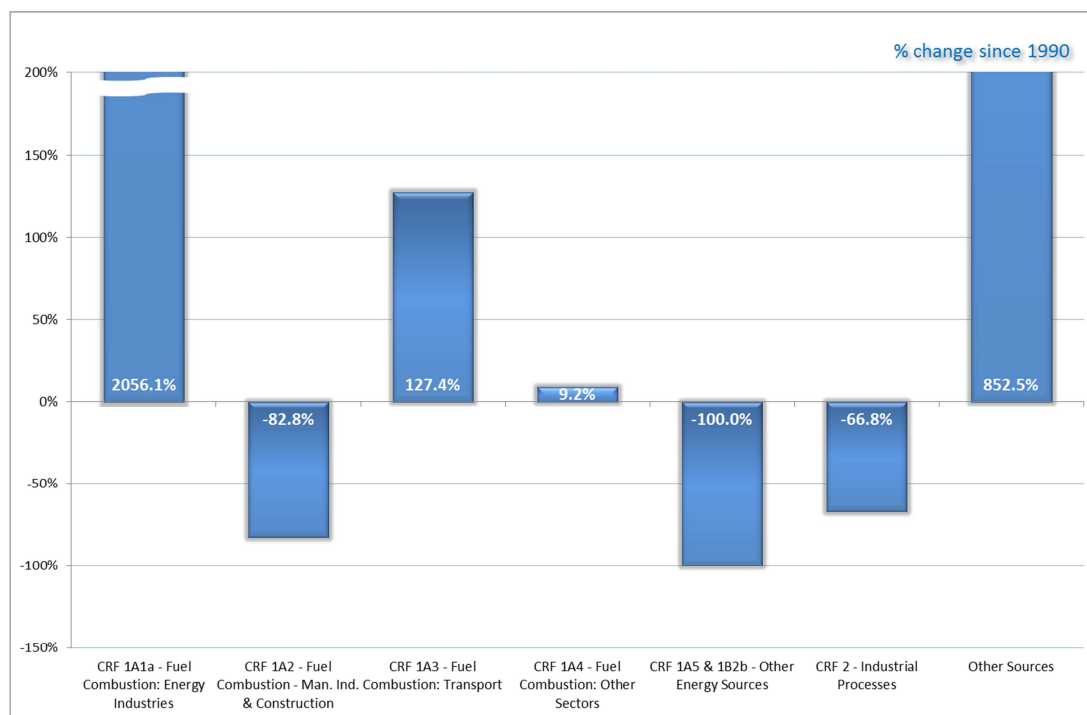
N<sub>2</sub>O



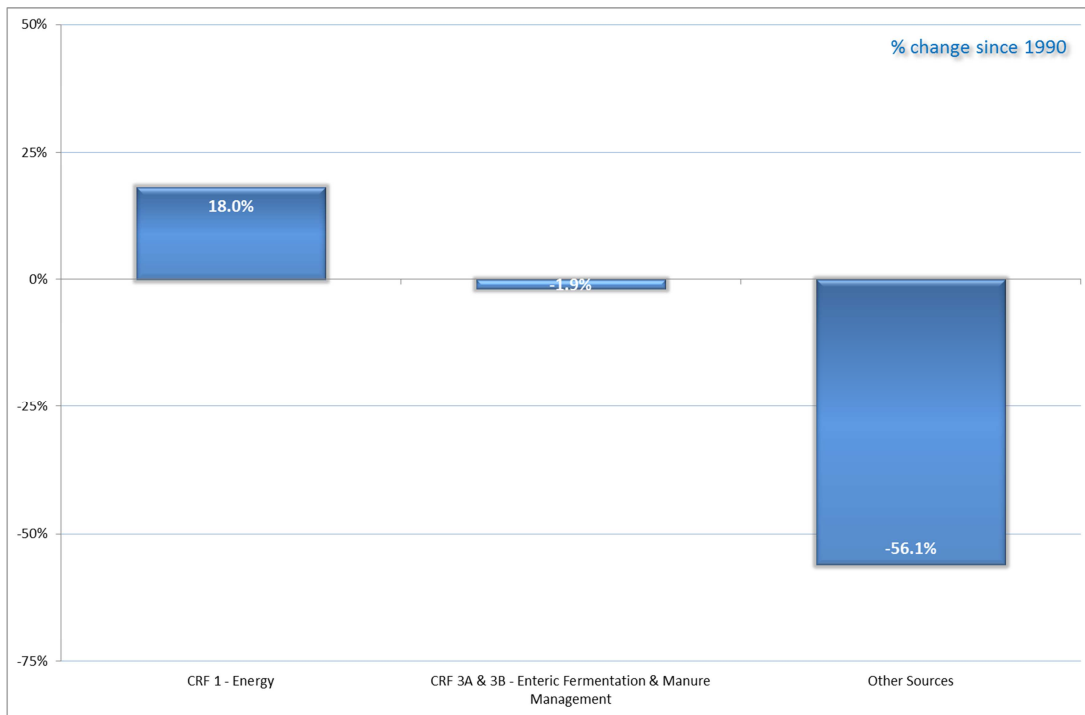
Sources: Environment Agency and MDDI-DEV.

Figure 2-30 – Luxembourg's GHG emission trends in % (excl. LULUCF) – details by main gases: 1990-2014

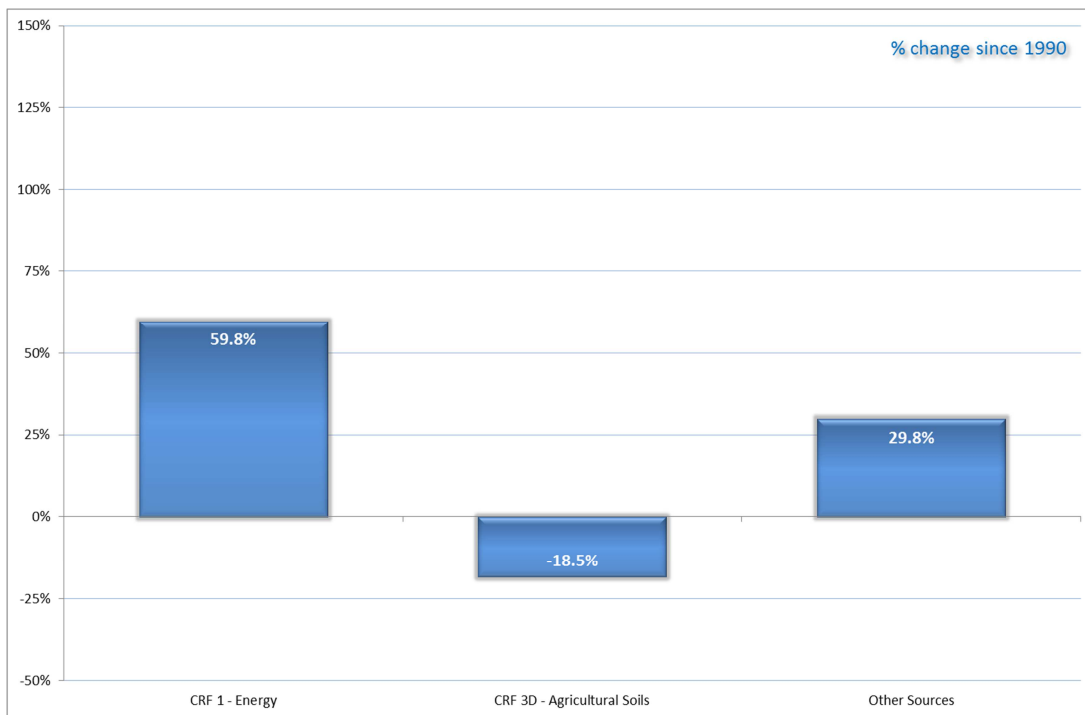
CO<sub>2</sub>



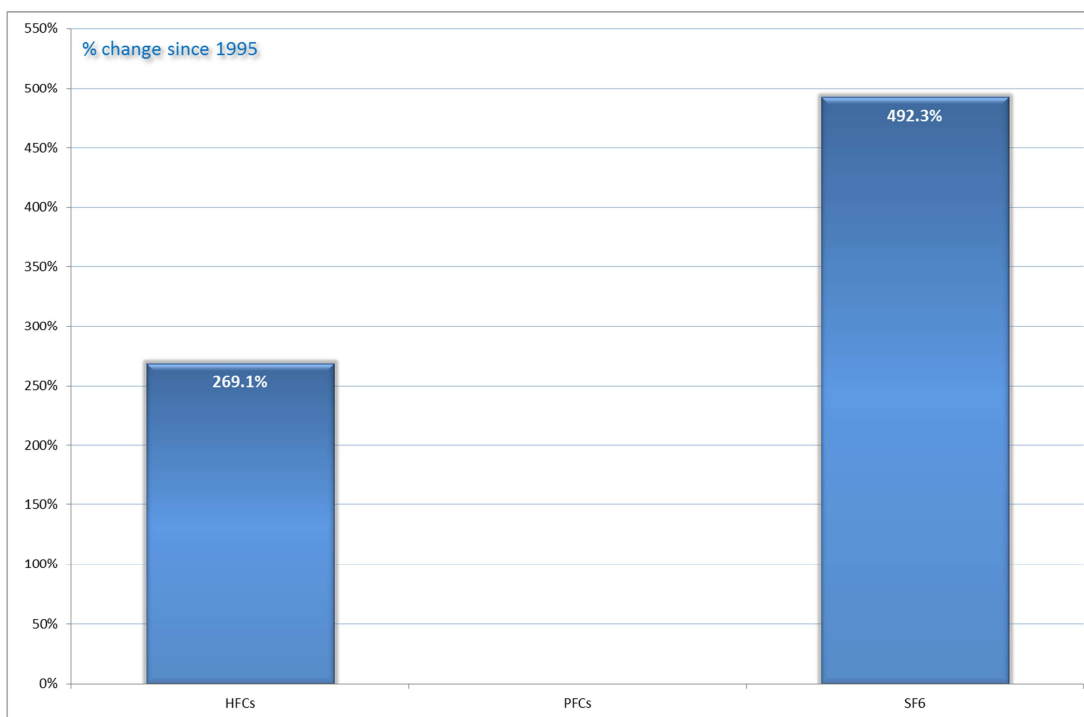
CH<sub>4</sub>



N<sub>2</sub>O



## F-gases



Sources: Environment Agency and MDDI-DEV.

### 2.3.1 Carbon dioxide – CO<sub>2</sub>

CRF (sub-) categories covered	1 (1A1, 1A2, 1A3, 1A4, 1A5, 1B2b), 2	
Share in total GHG emissions, excl. LULUCF	1990	92.9% = 11 961.50 Gg CO <sub>2</sub> e
	2014	91.3% = 9 829.93 Gg CO <sub>2</sub> e

Throughout the period 1990-2014, the main GHG has remained carbon dioxide, which accounted between 92.9% and 91.3% of the total GHG emissions. However, the structure of CO<sub>2</sub> emissions has evolved with an increase in fuel combustion, which accounted for 80.2% of total GHG emissions for the base year (1990) and climbed up to 86.16% in 2014, after having reached a maximum of 87.9 % 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 20.65% of total GHG emissions. Then, with 6.08 Mio. t CO<sub>2</sub>, this percentage reached 56.5% in 2014.<sup>72</sup> CO<sub>2</sub> emissions due solely to “road fuel sales to non-residents”

<sup>72</sup> The highest amount of emissions was recorded for the year 2005: 7.33 Mio. t CO<sub>2</sub> but “only” 54.6% of total GHG emissions. In fact, percentages are somewhat over-estimated in 2014 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).



amounted to about 1.8 Mio. t in 1990 and reached 4.5 Mio. t in 2014,<sup>73</sup> i.e. roughly a threefold increase (the same comparison shows only a twofold increase for road fuel consumed by the national vehicle fleet). In 2014, “road fuel sales to non-residents” represented 74.5% of CO<sub>2</sub> emissions of the transport sector and **42.1%** of the total CO<sub>2</sub> emissions.<sup>74</sup> In 1990, these percentages were 67.5% and **14%**, respectively.

Another important source of CO<sub>2</sub> 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<sub>4</sub>

CRF (sub-) categories covered	1, 3A, 3B, 5A, 5B, 5D		
Share in total GHG emissions, excl. LULUCF	<b>1990</b>	4.8% =	619.80 Gg CO <sub>2</sub> e
	<b>2014</b>	5.53% =	570.12 Gg CO <sub>2</sub> e

Methane emissions originate above all from the agricultural sector, and more precisely from **enteric fermentation** and from **manure production and management**: around 83.6% of methane emissions over the period 1990-2014. 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 (-47.3%) and growing emissions in **energy use** (+18.03%). 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<sub>2</sub>O

CRF (sub-) categories covered	1, 2G, 3B, 3D, 5B and 5D		
Share in total GHG emissions, excl. LULUCF	<b>1990</b>	2.27% =	288.77 Gg CO <sub>2</sub> e
	<b>2014</b>	2.9% =	298.84 Gg CO <sub>2</sub> e

A large part of nitrous oxide emissions is caused by **agricultural soils** that drive the -18.5% decline observed for this gas over the period 1990-2014. Another important source, generating increasing N<sub>2</sub>O emissions since 1990, is **road transportation**, where incomplete NO<sub>x</sub> reduction in catalytic converters of diesel oil motor vehicles leads to N<sub>2</sub>O emissions that were almost multiplied by a

<sup>73</sup> **5.45** Mio. t in 2005.

<sup>74</sup> For 2005, these percentages were respectively **78.8%** and **45.1%**.

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.

### 2.3.4 Hydrofluorocarbons – HFCs, perfluorocarbons - PFCs and sulphur hexafluoride – SF<sub>6</sub>

CRF (sub-) categories covered	2D, 2F, 2G		
Share in total GHG emissions, excl. LULUCF	1990	0.01% =	0.08 Gg CO <sub>2</sub> e
	2014	0.69% =	74.52 Gg CO <sub>2</sub> e

The increase in **HFCs** emissions between 1990 and 2014 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<sub>6</sub>** 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 2014, the energy sector accounted for almost 87.3% of the total GHG emissions, excluding LULUCF. Two sectors represent between 6% and 6.5% of the total emissions, excluding LULUCF: industrial processes (6%) and agriculture (6.24%). The remaining sector<sup>75</sup> (waste<sup>76</sup> (0.46%) 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 1990-2014 (and 2013-2014) were as follows:

- Energy: .....-9.7% (-4.9%)
- Industrial Processes: .....-60.9% (+5.9%)
- Agriculture: .....-6.0% (+1.86%)
- LULUCF: .....-983.21% (-14.51%)
- Waste: .....-48.1% (-1.9%)

<sup>75</sup> The sector "Others" is not reported for Luxembourg.

<sup>76</sup> 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).

### 2.4.1 CRF 1 – Energy

GHG covered	CO <sub>2</sub> , CH <sub>4</sub> & N <sub>2</sub> O	
Share in total GHG emissions, excl. LULUCF	1990	80.9% = 10 411.19 Gg CO <sub>2</sub> e
	2014	87.3% = 9 403.04 Gg CO <sub>2</sub> e

Energy production and consumption related GHG emissions have decreased by 9.7% between 1990 and 2014 from 10.4 Mio. t CO<sub>2</sub>e in 1990 to 9.4 Mio. t CO<sub>2</sub>e in 2014. For carbon dioxide, methane and nitrous oxide, the changes over the period 1990-2014 were -10.09%, +18.03% and +59.81%, 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): +1923.98% and +126.79%, respectively between 1990 and 2014 (+5.15% and -4.32% from 2013 to 2014) with, as a result, shares in the total energy related GHG emissions rising from 0.28% to 6.7% and 20.89% to 56.61%, respectively. For the other sub-sectors, the observed trends between 1990 and 2014 are -82.71% for **manufacturing industries and construction** (1A2), +9.31% for the **other sectors** (1A4), and +98.45% for **fugitive emissions from fuels** (1B).<sup>77</sup>

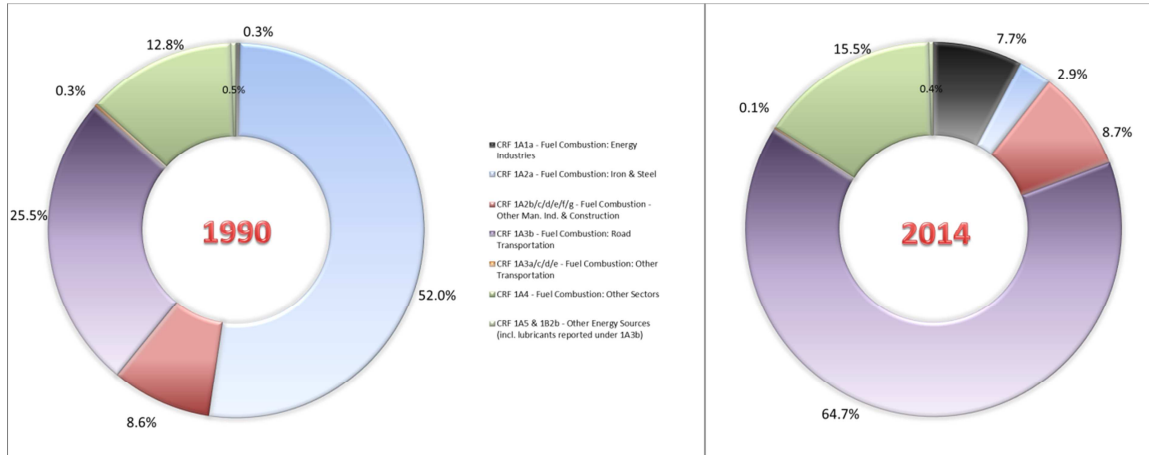
In fact, over the period, GHG emissions have been strongly influenced by varying fuel consumption levels in industry, in particular in the energy and the iron and steel industries, as well as in the road transport sector as percentage growths recorded for CRF sub-categories 1A1, 1A2 and 1A3 demonstrate. 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.

<sup>77</sup> Fugitive emission growth is closely linked to natural gas use in Luxembourg.

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).

**Figure 2-31 – CRF sub-categories share in GHG emissions for CRF 1 – Energy: 1990 & 2014**



Sources: Environment Agency and MDDI-DEV.

#### 2.4.2 CRF 2 – Industrial Processes

GHG covered	CO <sub>2</sub> & F-gases	
Share in total GHG emissions, excl. LULUCF	<b>1990</b>	12.8% = 1 648.46 Gg CO <sub>2</sub> e
	<b>2014</b>	6% = 645.78 Gg CO <sub>2</sub> e

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<sub>6</sub> (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.

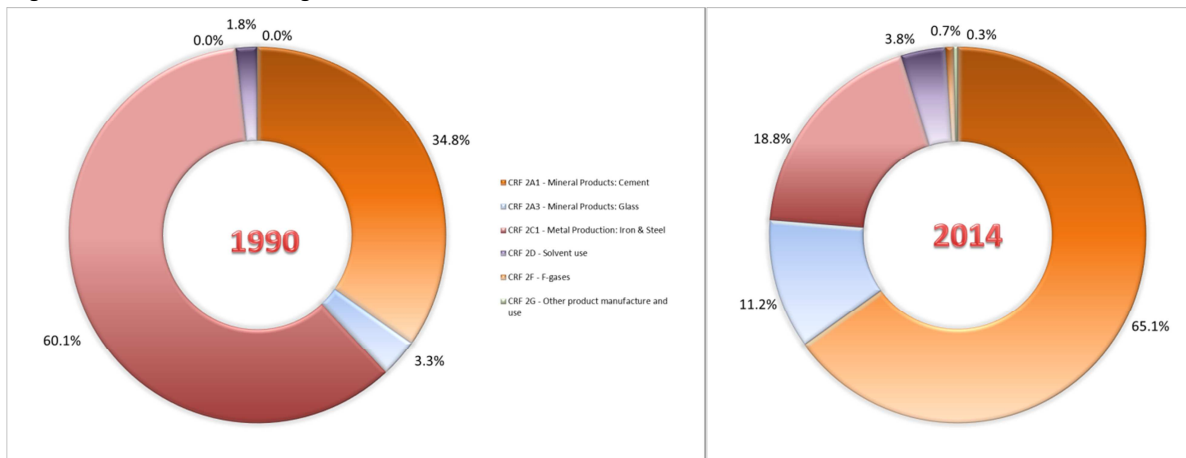
Emissions from industrial processes show a declining trend between 1990 and 1998, then a relative stabilisation. This evolution was mainly driven by **process changes that occurred in the iron & steel industry**. As indicated above, this industry moved from blast to electric arc furnaces between 1994 and 1998. As a consequence, steel industry process emissions in CO<sub>2</sub>e decreased by 89.6% over the period 1990-2014. Overall sector emissions in CO<sub>2</sub>e fell by about 66.8% between 1990 and 2014, reducing the weight of this sector in total GHG emissions from 12.7% to 5.5% over the period. By gas, however, the picture is different. For carbon dioxide, the decrease over the period

1990-2014 was -66.8%: -37.9% for 2A1, +14.01% for 2A3 and -89.6% for 2C1. F-gases emissions, on the contrary, increased regularly: +286.25% over the period 1995-2014 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 & 2014**



Sources: Environment Agency and MDDI-DEV.

### 2.4.3 CRF 3 – Agriculture

GHG covered	CH <sub>4</sub> & N <sub>2</sub> O		
Share in total GHG emissions, excl. LULUCF	<b>1990</b>	5.56% =	715.22 Gg CO <sub>2</sub> e
	<b>2014</b>	6.24% =	671.93 Gg CO <sub>2</sub> e

Trends in agriculture were also favourable between 1990 and 2014: in general GHG related to agricultural activities have decreased by 6.1% (-1.9% for methane and -17.2% for nitrous oxide). Enteric Fermentation (3A) saw its emissions declining by 4.18%, whereas for agricultural soils (3D), the decrease reaches 18.49%. For manure management (3B), emissions remained quite stable between 1990 and 2014 (+5.13%), though opposite variations are observed for the two GHG emitted by this activity: methane declined by -1.9% and nitrous oxide increased by 18.5%.

- 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 2014, 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 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.

Figure 2-33.

Looking at each CRF category in more detail, generally the decrease in **enteric fermentation** related **methane** emanations over the period 1990-2014 is mainly the result from declining emissions generated by cattle – -9.7% for dairy cattle and -12.9% for non-dairy cattle – whilst increasing emissions were recorded for the other livestock categories, except rabbits. With regard to cattle, its total population size declined throughout the period 1990-2014 driven by a decline in dairy cattle heads – non-dairy cattle population in 2014 is only 13% below its 1990 level. However, a shift did occur within the cattle population with a reduction for dairy cattle (-21%) and an increase for female mature non-dairy cattle (+54.7%). 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).<sup>78</sup> Finally, if the dairy cattle population decreased by 21% between 1990 and 2014, related methane emissions only declined by 9.7%. 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 17.3% can be observed for the period 1990-2014. Animals who did contribute the most to these emissions were cattle and swine. As far as **nitrous oxide** emissions from **manure management** are concerned, a decrease of 11.1% is observed for the period 1990-2014. These emissions are mainly due to cattle. However, if cattle were responsible for 94% of manure related N<sub>2</sub>O emissions in 1990, this share dropped to a bit less than 88% in 2014. 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.

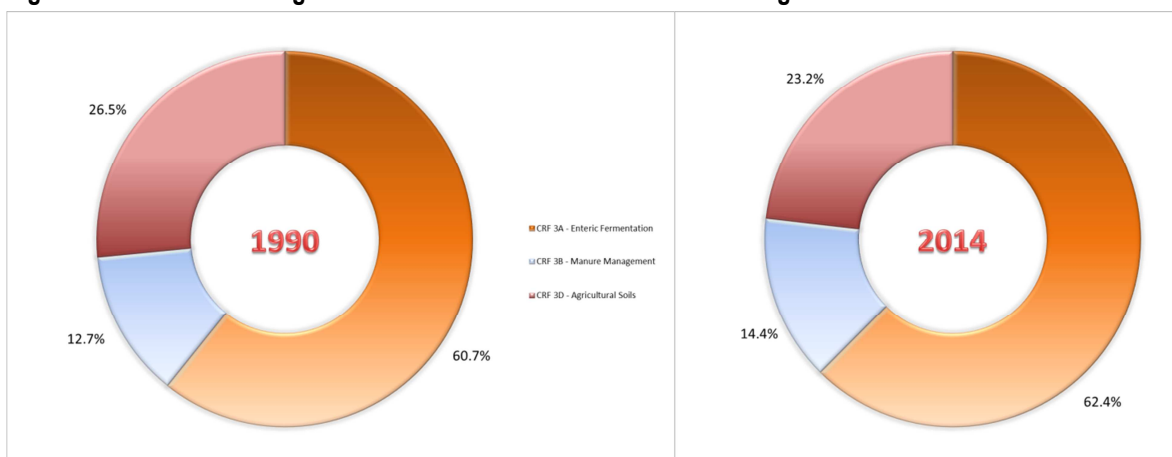
Finally, **nitrous oxide** emissions from **agricultural soils** are mainly driven by:

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<sup>78</sup> 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.

- 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.

**Figure 2-33 –CRF sub-categories share in GHG emissions for CRF 3 – Agriculture: 1990 & 2014**



Source: MDDI-DEV.

#### 2.4.4 CRF 5 – Waste

GHG covered	CH <sub>4</sub> & N <sub>2</sub> O		
Share in total GHG emissions, excl. LULUCF	<b>1990</b>	0.75% =	96.08 Gg CO <sub>2</sub> e
	<b>2014</b>	0.46% =	49.83 Gg CO <sub>2</sub> e

In the waste sector, the main source of GHG was solid waste disposal on land (5A), but its weight decreased over the period 1990-2014 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 2014 (-63.8%) still drove a reduction for the overall waste sector despite composting rising emissions. Wastewater handling emissions (5D) experienced a 29.38% decline in emissions between 1990 and 2014. 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.

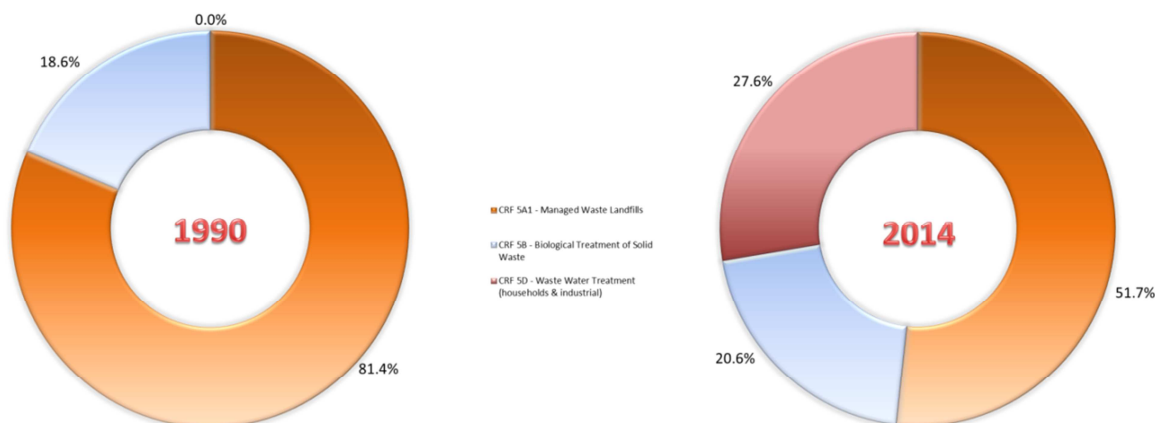
**Wastewater** treatment plant (WWTP) capacities expressed in population-equivalents have steadily grown since 1990. However, methane and nitrous oxide emissions decreased by 47.3% since 1990. Therefore, technical changes, with regard to wastewater treatment, have had an undeniable role too.

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.<sup>79</sup> 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 & 2014**



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

<sup>79</sup> See Table 8-17 in Section 8.5.2.2.



#### 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.

### 2.5 Description of Emission Trends of Indirect GHG and SO<sub>2</sub>

Indirect GHG – NO<sub>x</sub>, CO, NMVOCs – and SO<sub>2</sub> 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.<sup>80</sup>

### 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.<sup>81</sup> 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<sub>2</sub>, whereas other categories and sub-categories reported in the inventory are generally sources of emissions (both CO<sub>2</sub> and N<sub>2</sub>O).

Luxembourg has chosen **to account for the activities under Article 3.3** of the Kyoto Protocol for the whole commitment period but **does not plan to account for net emissions and removals from activities under Article 3.4** of the same Protocol since, for the moment, there is a lack of reliable data allowing to produce realistic estimates of the activities covered under Article 3.4.

The latest inventory shows potential net sinks over the first Kyoto commitment period 2008-2012. Indeed, from the "Accounting" KP-LULUCF table, the expected net carbon sequestration from LULUCF activities (or "Removal Units" – RMUs) would reach 70.5 Gg of CO<sub>2</sub>e.<sup>82</sup> 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.

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<sup>80</sup> [http://www.ceip.at/ms/ceip\\_home1/ceip\\_home/status\\_reporting/2016\\_submissions/](http://www.ceip.at/ms/ceip_home1/ceip_home/status_reporting/2016_submissions/)

<sup>81</sup> Net emissions in 1990 and 1991 are the consequence of the important storms that severely hit Luxembourg's forests in early 1989-90.

<sup>82</sup> 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 CO<sub>2</sub>e. In the SEF tables, no RMUs are accounted for yet).

With regard to the KP-LULUCF activities, in 2014, CO<sub>2</sub> removals from **afforestation and reforestation** (AR) in Luxembourg amounted to -176.28 Gg CO<sub>2</sub>. -119.13 Gg CO<sub>2</sub> resulted from accumulation of biomass, -5.45 Gg CO<sub>2</sub> resulted from accumulation of dead wood, -18.61 Gg CO<sub>2</sub> from accumulation of litter, -33.09 Gg CO<sub>2</sub> from accumulation of carbon stock in soils.

Emissions from **deforestation** (D) activities amounted in 2014 to 41.78 Gg CO<sub>2</sub>. 17.00 Gg CO<sub>2</sub> resulted from loss of biomass, 0.81 from loss of dead wood, 2.77 Gg CO<sub>2</sub> from loss of litter, 21.20 Gg CO<sub>2</sub> 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.

## 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 3 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 2014.

GHG emissions from fossil fuel combustion are the main source of greenhouse gas emissions in the Grand-Duchy of Luxembourg. In 2014, about 86.95% 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 0.36% 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 2014 for each of the IPCC categories under CRF Sector 1 - *Energy*, for which GHG emissions are reported. These are expressed in CO<sub>2</sub> equivalents and include CH<sub>4</sub> and N<sub>2</sub>O emissions from biomass, but exclude CO<sub>2</sub> emissions from biomass combustion. CO<sub>2</sub> emissions from biomass combustion are automatically reported under *Memory Items* and are not accounted 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 9.89% between 1990 and 2014 from 10.39 million tonnes CO<sub>2</sub> equivalents in 1990 to 9.36 million tonnes CO<sub>2</sub> equivalents in 2014. Carbon dioxide emissions decreased by 10.1% in 2014 compared to the base

year. Methane emissions decreased by 39.2%, whereas nitrous oxide emissions increased by 59.8%, for the same period.

**Figure 3-1 – GHG emission trends for CRF Sector 1-Energy: 1990-2014**

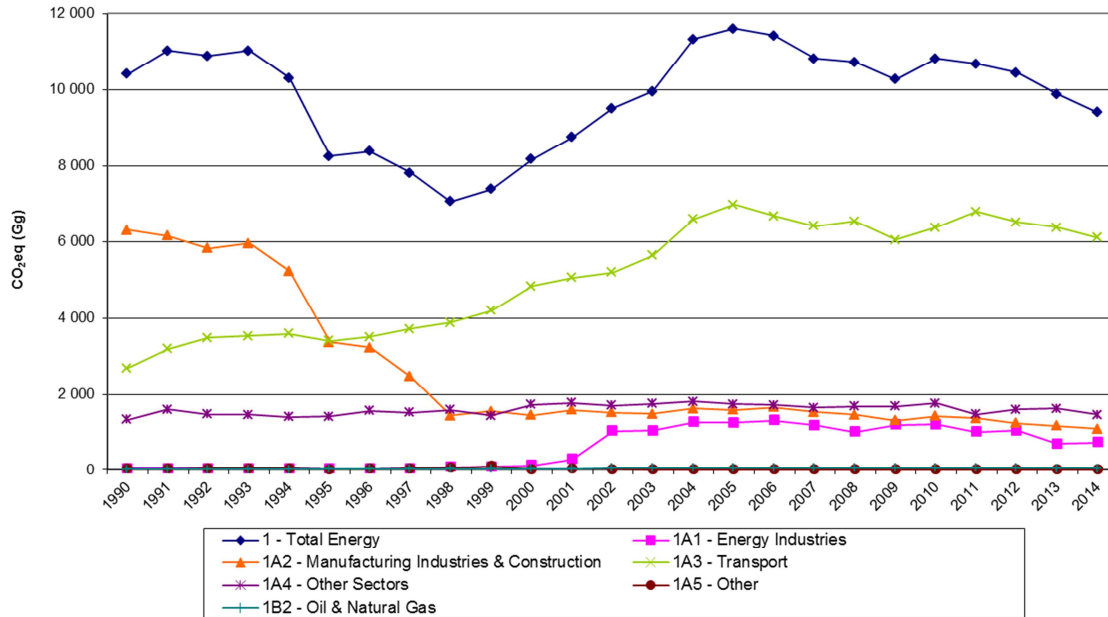


Figure 3-2 illustrates that the overall trend observed at sector level hides very different developments at the sub-category level. Indeed, between 1990 and 2014, GHG emissions have been strongly influenced by varying fuel consumption levels in industry, in particular in the iron and steel industry, 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<sup>83</sup>, 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

<sup>83</sup> 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 CO2e for CRF Sector 1 – Energy: 1990-2014

1 - Energy																
GHG emissions by source & sink category (Gg)																
Year	1A1 - Energy Industries				1A2 - Manufacturing Industries & Construction				1A3 - Transport				1A4 - Other Sectors			
	Total CO <sub>2</sub> eq	CO <sub>2</sub> (excl. biomass)	CH <sub>4</sub> (incl. biomass)	N <sub>2</sub> O (incl. biomass)	Total CO <sub>2</sub> eq	CO <sub>2</sub> (excl. biomass)	CH <sub>4</sub> (incl. biomass)	N <sub>2</sub> O (incl. biomass)	Total CO <sub>2</sub> eq	CO <sub>2</sub> (excl. biomass)	CH <sub>4</sub> (incl. biomass)	N <sub>2</sub> O (incl. biomass)	Total CO <sub>2</sub> eq	CO <sub>2</sub> (excl. biomass)	CH <sub>4</sub> (incl. biomass)	N <sub>2</sub> O (incl. biomass)
1990	35.64	33.29	0.04	0.00	6 305.20	6 287.64	0.16	0.05	2 688.26	2 657.87	0.46	0.06	1 331.81	1 316.90	0.43	0.01
1991	36.41	34.01	0.04	0.00	6 144.74	6 127.18	0.16	0.05	3 191.22	3 155.68	0.51	0.08	1 600.00	1 583.16	0.48	0.02
1992	37.19	34.73	0.04	0.01	5 819.43	5 800.53	0.15	0.05	3 483.88	3 445.11	0.50	0.09	1 474.53	1 458.87	0.44	0.02
1993	35.38	33.04	0.04	0.00	5 945.74	5 927.43	0.15	0.05	3 527.93	3 488.30	0.46	0.09	1 456.94	1 441.49	0.44	0.01
1994	34.61	32.32	0.04	0.00	5 225.52	5 207.86	0.15	0.05	3 588.73	3 547.23	0.43	0.10	1 399.20	1 384.54	0.41	0.01
1995	33.06	30.87	0.03	0.00	3 365.60	3 350.99	0.10	0.04	3 408.03	3 368.66	0.37	0.10	1 411.15	1 396.44	0.42	0.01
1996	26.45	24.76	0.03	0.00	3 224.20	3 208.90	0.10	0.04	3 510.81	3 470.55	0.35	0.11	1 563.78	1 548.80	0.41	0.02
1997	38.78	36.77	0.03	0.00	2 474.86	2 458.49	0.08	0.05	3 714.11	3 673.16	0.34	0.11	1 519.81	1 504.80	0.41	0.02
1998	69.48	67.01	0.04	0.01	1 435.40	1 419.07	0.06	0.05	3 883.15	3 842.73	0.31	0.11	1 590.75	1 575.56	0.41	0.02
1999	81.03	78.19	0.04	0.01	1 555.07	1 544.83	0.07	0.03	4 188.88	4 147.97	0.29	0.11	1 433.77	1 420.50	0.39	0.01
2000	120.17	117.37	0.04	0.01	1 451.28	1 440.66	0.07	0.03	4 837.74	4 795.61	0.27	0.12	1 724.14	1 705.68	0.40	0.03
2001	282.26	279.33	0.05	0.01	1 588.50	1 575.41	0.08	0.04	5 053.81	5 012.76	0.25	0.12	1 769.12	1 749.24	0.42	0.03
2002	1 029.32	1 025.62	0.06	0.01	1 515.50	1 496.91	0.07	0.06	5 196.59	5 157.80	0.22	0.11	1 706.22	1 687.41	0.39	0.03
2003	1 037.21	1 033.38	0.06	0.01	1 477.27	1 445.79	0.07	0.10	5 631.86	5 593.71	0.21	0.11	1 753.93	1 734.80	0.40	0.03
2004	1 261.58	1 257.24	0.07	0.01	1 616.92	1 586.49	0.07	0.10	6 585.22	6 547.30	0.20	0.11	1 810.77	1 791.50	0.41	0.03
2005	1 243.98	1 239.93	0.07	0.01	1 587.82	1 559.96	0.10	0.09	6 978.24	6 942.54	0.17	0.11	1 742.88	1 724.45	0.40	0.03
2006	1 308.02	1 303.70	0.07	0.01	1 654.14	1 629.40	0.11	0.07	6 675.26	6 641.74	0.15	0.10	1 720.88	1 702.81	0.39	0.03
2007	1 184.14	1 179.86	0.07	0.01	1 533.44	1 512.43	0.10	0.06	6 409.18	6 373.47	0.13	0.11	1 640.06	1 622.98	0.36	0.03
2008	999.75	995.52	0.07	0.01	1 455.32	1 438.73	0.10	0.05	6 535.92	6 496.43	0.11	0.12	1 682.31	1 664.84	0.38	0.03
2009	1 195.44	1 191.11	0.07	0.01	1 304.80	1 291.59	0.08	0.04	6 041.05	6 001.40	0.10	0.12	1 678.43	1 660.08	0.40	0.03
2010	1 207.30	1 203.27	0.07	0.01	1 419.12	1 404.80	0.10	0.04	6 372.17	6 328.05	0.09	0.14	1 762.75	1 744.19	0.42	0.03
2011	1 003.11	999.04	0.07	0.01	1 364.04	1 352.33	0.09	0.03	6 788.89	6 738.39	0.09	0.16	1 475.41	1 460.58	0.34	0.02
2012	1 039.49	1 035.44	0.07	0.01	1 239.42	1 229.98	0.08	0.02	6 513.47	6 462.51	0.08	0.16	1 602.93	1 586.37	0.40	0.02
2013	686.10	682.30	0.06	0.01	1 164.16	1 155.07	0.08	0.02	6 371.75	6 320.41	0.07	0.17	1 622.51	1 604.16	0.45	0.02
2014	721.42	717.70	0.06	0.01	1 090.64	1 079.88	0.09	0.03	6 096.72	6 044.32	0.09	0.17	1 455.79	1 438.38	0.43	0.02
Trend 1990-2014	1923.98%	2056.08%	62.79%	54.67%	-82.70%	-82.83%	-44.83%	-36.95%	126.79%	127.41%	-81.41%	166.62%	9.31%	9.23%	-0.20%	60.09%
Trend 2013-2014	5.15%	5.19%	-1.82%	-2.24%	-6.32%	-6.51%	4.57%	22.50%	-4.32%	-4.37%	24.15%	1.28%	-10.28%	-10.33%	-4.90%	-5.53%

Note: Table continues on next page.

# 1 - Energy

## GHG emissions by source & sink category (Gg)

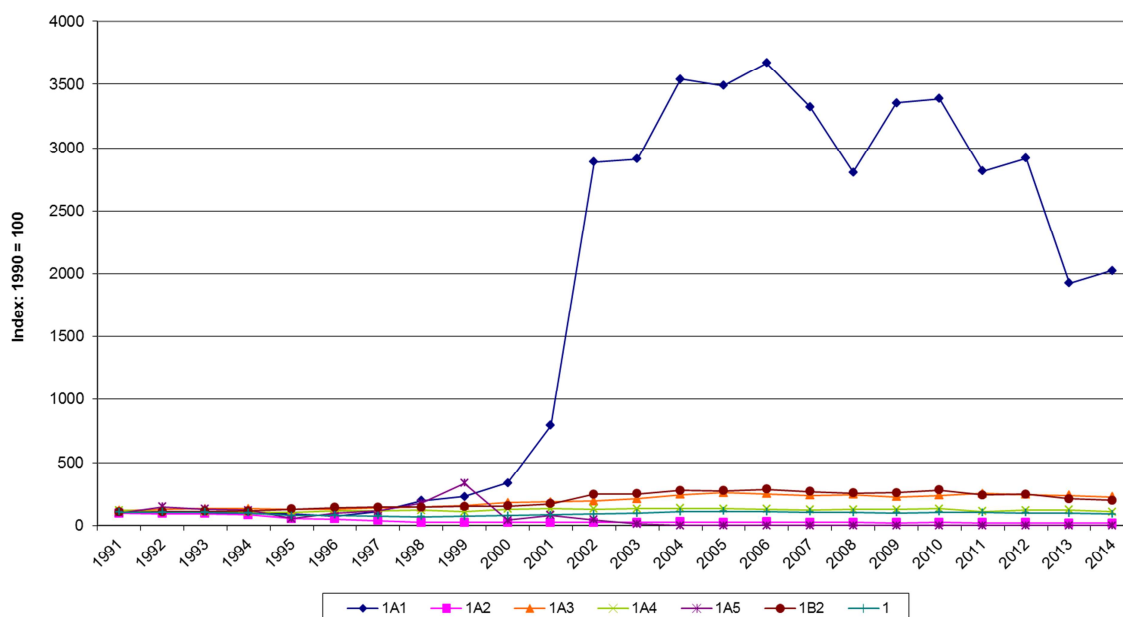
Year	1A5 - Other				1B2 - Oil & Natural Gas				1 - Total Energy			
	Total CO <sub>2</sub> eq	CO <sub>2</sub> (excl. biomass)	CH <sub>4</sub> (incl. biomass)	N <sub>2</sub> O (incl. biomass)	Total CO <sub>2</sub> eq	CO <sub>2</sub> (excl. biomass)	CH <sub>4</sub> (incl. biomass)	N <sub>2</sub> O (incl. biomass)	Total CO <sub>2</sub> eq	CO <sub>2</sub> (excl. biomass)	CH <sub>4</sub> (incl. biomass)	N <sub>2</sub> O (incl. biomass)
1990	29.26	26.51	0.002	0.009	19.39	0.03	0.77	NA, NO	10 409.57	10 322.24	1.86	0.14
1991	29.27	26.51	0.002	0.009	20.11	0.03	0.80	NA, NO	11 021.76	10 926.56	1.99	0.15
1992	43.10	41.23	0.004	0.006	20.99	0.03	0.84	NA, NO	10 879.11	10 780.50	1.98	0.17
1993	37.74	36.12	0.004	0.005	21.79	0.03	0.87	NA, NO	11 025.52	10 926.40	1.96	0.17
1994	35.05	33.56	0.003	0.005	21.94	0.03	0.88	NA, NO	10 305.05	10 205.55	1.90	0.17
1995	16.11	15.49	0.002	0.002	25.01	0.03	1.00	NA, NO	8 258.96	8 162.48	1.93	0.16
1996	29.32	28.08	0.003	0.004	27.36	0.04	1.09	NA, NO	8 381.92	8 281.12	1.99	0.17
1997	33.85	32.59	0.003	0.004	27.98	0.04	1.12	NA, NO	7 809.38	7 705.85	1.98	0.18
1998	51.49	49.49	0.005	0.006	28.20	0.04	1.13	NA, NO	7 058.47	6 953.89	1.95	0.19
1999	98.00	94.01	0.010	0.013	29.20	0.04	1.17	NA, NO	7 385.95	7 285.54	1.96	0.17
2000	12.08	12.05	0.001	0.000	29.98	0.04	1.20	NA, NO	8 175.39	8 071.40	1.98	0.18
2001	24.10	24.04	0.002	0.000	33.32	0.04	1.33	NA, NO	8 751.11	8 640.83	2.12	0.19
2002	13.40	13.37	0.001	0.000	47.72	0.06	1.91	NA, NO	9 508.75	9 381.17	2.65	0.21
2003	3.14	3.13	0.000	0.000	48.36	0.06	1.93	NA, NO	9 951.77	9 810.88	2.67	0.25
2004	NO	NO	NO	NO	53.67	0.07	2.14	NA, NO	11 328.15	11 182.60	2.90	0.25
2005	NO	NO	NO	NO	52.87	0.07	2.11	NA, NO	11 605.79	11 466.96	2.85	0.23
2006	NO	NO	NO	NO	55.48	0.07	2.22	NA, NO	11 413.77	11 277.72	2.93	0.21
2007	NO	NO	NO	NO	51.91	0.07	2.07	NA, NO	10 818.73	10 688.81	2.73	0.21
2008	NO	NO	NO	NO	49.64	0.07	1.98	NA, NO	10 722.93	10 595.59	2.65	0.21
2009	NO	NO	NO	NO	50.18	0.07	2.00	NA, NO	10 269.89	10 144.25	2.66	0.20
2010	NO	NO	NO	NO	53.96	0.07	2.16	NA, NO	10 815.31	10 680.38	2.82	0.22
2011	NO	NO	NO	NO	46.78	0.06	1.87	NA, NO	10 678.22	10 550.40	2.45	0.22
2012	NO	NO	NO	NO	47.85	0.06	1.91	NA, NO	10 443.17	10 314.36	2.53	0.22
2013	NO	NO	NO	NO	40.74	0.05	1.63	NA, NO	9 885.26	9 761.99	2.29	0.22
2014	NO	NO	NO	NO	38.47	0.05	1.54	NA, NO	9 403.04	9 280.34	2.20	0.23
<b>Trend 1990-2014</b>	NA	NA	NA	NA	98.45%	98.45%	98.45%	NA	-9.67%	-10.09%	18.03%	66.15%
<b>Trend 2013-2014</b>	NA	NA	NA	NA	-5.57%	-5.57%	-5.57%	NA	-4.88%	-4.93%	-4.07%	2.68%

Source: Environment Agency.

Notes: CH<sub>4</sub> emissions are converted in CO<sub>2</sub>e 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.

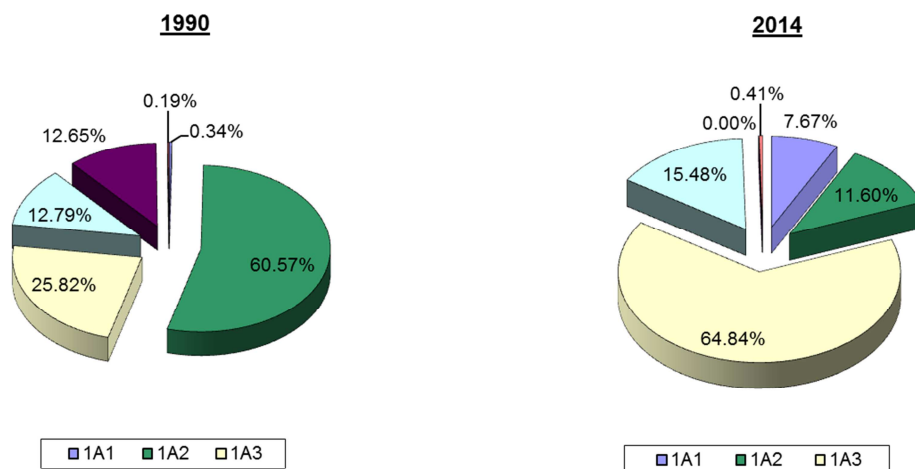
N<sub>2</sub>O emissions are converted in CO<sub>2</sub>e by multiplying the emissions by 298, i.e. the global warming potential (GWP) value for nitrous oxide based on the effects of GHG over a 100-year time horizon.

**Figure 3-2 – GHG emission trend indexes for CRF Sector 1 – Energy: 1990-2014**



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 2014 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 2014**





**Table 3-2– Final energy consumption trends: 1990-2014**

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	149 623	4 595	NA	28 126	20 790	538	94 645	930
2001	156 701	4 958	NA	27 998	21 033	668	100 723	1 321
2002	158 279	3 084	NA	28 258	21 261	1 150	103 120	1 406
2003	168 431	2 369	NA	28 674	22 252	2 907	110 822	1 407
2004	186 730	3 329	NA	29 942	23 007	3 149	125 715	1 587
2005	190 571	3 249	NA	29 338	22 149	3 173	130 171	2 490
2006	187 806	3 877	NA	30 623	23 806	3 333	123 605	2 562
2007	184 957	3 280	NA	29 823	24 098	2 696	120 542	4 519
2008	186 744	3 137	NA	30 616	23 750	3 056	121 488	4 697
2009	173 845	2 801	NA	28 659	22 005	2 622	113 538	4 219
2010	184 546	2 807	NA	31 412	23 777	3 200	118 811	4 539
2011	182 787	2 443	NA	27 916	23 503	3 276	121 234	4 415
2012	177 824	2 250	NA	28 262	22 571	3 246	116 796	4 700
2013	175 848	2 006	NA	27 790	22 432	3 467	114 950	5 203
2014	170 158	2 235	NA	25 257	22 418	3 834	110 461	5 953
<b>Trend 1990-2014</b>	18.13%	-93.49%	NA	30.01%	49.57%	NA	66.88%	823.28%
<b>Share 1990</b>	100.00%	23.83%	5.87%	13.49%	10.41%	NA	45.95%	0.45%
<b>Share 2014</b>	100.00%	1.31%	NA	14.84%	13.17%	2.25%	64.92%	3.50%

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 18th January 2016 (subject to change since that date)

Final energy consumption increased by 18.1% between 1990 and 2014 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 2014, 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 2014, with 64.9% 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 2014, almost 74.5% of road fuels are sold to vehicles registered abroad (see Table 3-56 in Section 3.2.8.3).

The importance of natural gas has increased constantly and significantly since 1990. In 2014, 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<sup>84</sup>. 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 development site at Esch-Belval. Almost all of these 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.

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<sup>84</sup> This cannot be seen in final energy consumption statistics but only in the primary energy consumption figures.

**Table 3-3 – Electricity production trends: 1990-2014**

Year	<i>Electricity production (GWh)</i>			
	Total	Thermic <sup>(1)</sup>	RES <sup>(2)</sup>	Cogeneration <sup>(3)</sup>
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	100	148	2 396
2012	2 746	96	204	2 446
2013	1 842	95	267	1 480
2014	1 899	89	277	1 533
<b>Trend 1990-2014</b>	203.19%	-84.04%	309.84%	NA
<b>Share 1990</b>	100.00%	89.22%	10.78%	NA
<b>Share 2014</b>	100.00%	4.70%	14.57%	80.73%

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 Jan 18 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<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O**

GHG source & sink category	Description	Status		
		CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
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 (2000-2014)	X (2000-2014)	X (2000-2014)
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	NA	NA	NA
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	X	X
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	CO <sub>2</sub> 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 2014, GHG emissions of category 1A - *Fuel Combustion* amounted to a total of 9.36 million tonnes CO<sub>2</sub>e (see Table 3-5). The transport sector (1A3 - *Transport*) represented the most important source, with a share of 65.1% of the GHG emissions within category 1A (54.4% 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 15.55% of the GHG emissions within category 1A (12.99% of national total excl. LULUCF), followed by the energy sector (1A1 - *Energy*) and the industrial sector (1A2 - *Manufacturing Industries and Construction*) with shares of 7.7% and 11.6%, respectively (6.4% and 9.7% of national total excl. LULUCF, respectively). No emissions from sub-category 1A5 - *Other*, which includes emissions from other non-specified sources, were recorded in 2014.

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

1A - Fuel Combustion						
GHG emissions by source category excluding CO <sub>2</sub> emissions from biomass (CO <sub>2</sub> eq Gg)						
Year	1A1 Energy Industries	1A2 Manufacturing Industries & Construction	1A3 Transportation	1A4 Other Sectors	1A5 Other	1A Fuel Combustion
1990	35.6	6 305.2	2 688.3	1 331.8	29.3	10 390.2
1991	36.4	6 144.7	3 191.2	1 600.0	29.3	11 001.6
1992	37.2	5 819.4	3 483.9	1 474.5	43.1	10 858.1
1993	35.4	5 945.7	3 527.9	1 456.9	37.7	11 003.7
1994	34.6	5 225.5	3 588.7	1 399.2	35.1	10 283.1
1995	33.1	3 365.6	3 408.0	1 411.1	16.1	8 233.9
1996	26.4	3 224.2	3 510.8	1 563.8	29.3	8 354.6
1997	38.8	2 474.9	3 714.1	1 519.8	33.8	7 781.4
1998	69.5	1 435.4	3 883.1	1 590.7	51.5	7 030.3
1999	81.0	1 555.1	4 188.9	1 433.8	98.0	7 356.7
2000	120.2	1 451.3	4 837.7	1 724.1	12.1	8 145.4
2001	282.3	1 588.5	5 053.8	1 769.1	24.1	8 717.8
2002	1 029.3	1 515.5	5 196.6	1 706.2	13.4	9 461.0
2003	1 037.2	1 477.3	5 631.9	1 753.9	3.1	9 903.4
2004	1 261.6	1 616.9	6 585.2	1 810.8	NO	11 274.5
2005	1 244.0	1 587.8	6 978.2	1 742.9	NO	11 552.9
2006	1 308.0	1 654.1	6 675.3	1 720.9	NO	11 358.3
2007	1 184.1	1 533.4	6 409.2	1 640.1	NO	10 766.8
2008	999.8	1 455.3	6 535.9	1 682.3	NO	10 673.3
2009	1 195.4	1 304.8	6 041.0	1 678.4	NO	10 219.7
2010	1 207.3	1 419.1	6 372.2	1 762.8	NO	10 761.4
2011	1 003.1	1 364.0	6 788.9	1 475.4	NO	10 631.4
2012	1 039.5	1 239.4	6 513.5	1 602.9	NO	10 395.3
2013	686.1	1 164.2	6 371.7	1 622.5	NO	9 844.5
2014	721.4	1 090.6	6 096.7	1 455.8	NO	9 364.6
<b>Trend 1990-2014</b>	1923.98%	-82.70%	126.79%	9.31%	NA	-9.87%
<b>Share 1990</b>	0.34%	60.68%	25.87%	12.82%	0.28%	100.00%
<b>Share 2014</b>	7.70%	11.65%	65.10%	15.55%	NA	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 <sub>2</sub>	01-14	02-14		
1A1	Energy Industries	other	CO <sub>2</sub>	98-99, 02, 07-14			
1A2	Manufacturing Industries and Construction	gaseous	CO <sub>2</sub>	90-14	90-14	X	X
1A2	Manufacturing Industries and Construction	liquid	CO <sub>2</sub>	90-14	90-91, 10-11		X
1A2	Manufacturing Industries and Construction	solid	CO <sub>2</sub>	90-14	90-97, 10	X	X
1A3b	Road Transportation	diesel oil	CO <sub>2</sub>	90-14	90-14	X	X
1A3b	Road Transportation	gasoline	CO <sub>2</sub>	90-14	90-14	X	X
1A4	Other Sectors	gaseous	CO <sub>2</sub>	90-14	90-91, 95-14	X	X
1A4	Other Sectors	liquid	CO <sub>2</sub>	90-14	90-14	X	X
1A5	Other	liquid	CO <sub>2</sub>	99			

Sources: Environment Agency

Notes: LA = Level Assessment including respectively excluding LULUCF

TA = Trend Assessment including respectively excluding LULUCF

MIC = Manufacturing Industries and Construction

### 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

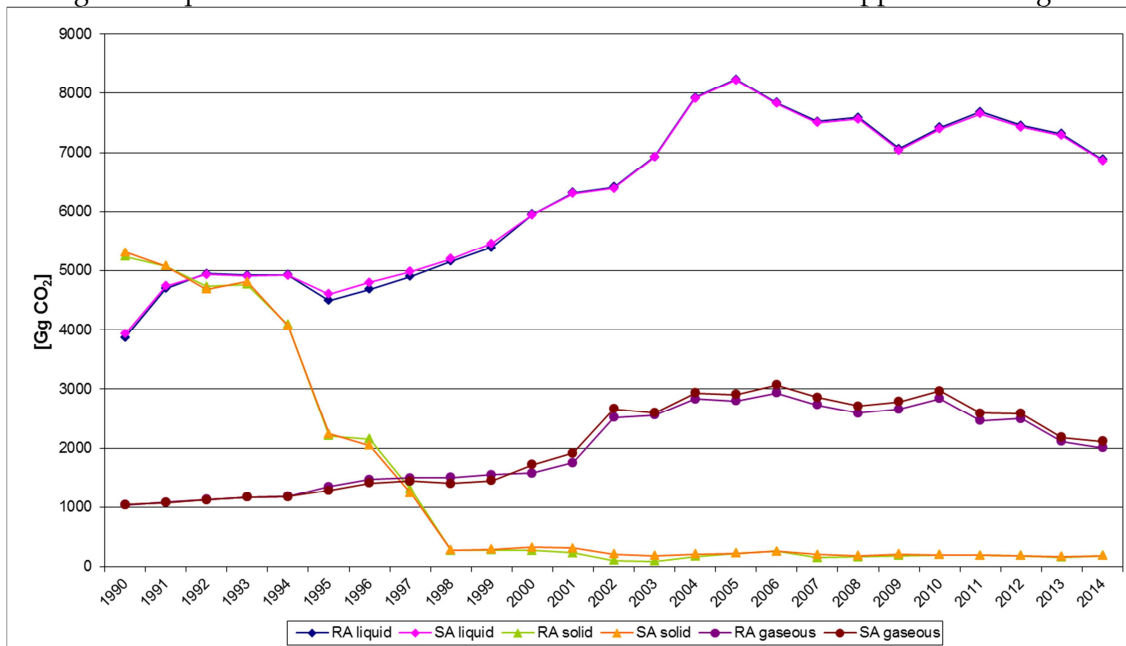


Table 3-7 present CO<sub>2</sub> emissions of the sectoral and the reference approaches. Gaseous fuels show the most significant differences starting from 2000 onwards.

Figure 3-4 - CO<sub>2</sub> Reference and Sectoral Approach 1990-2014

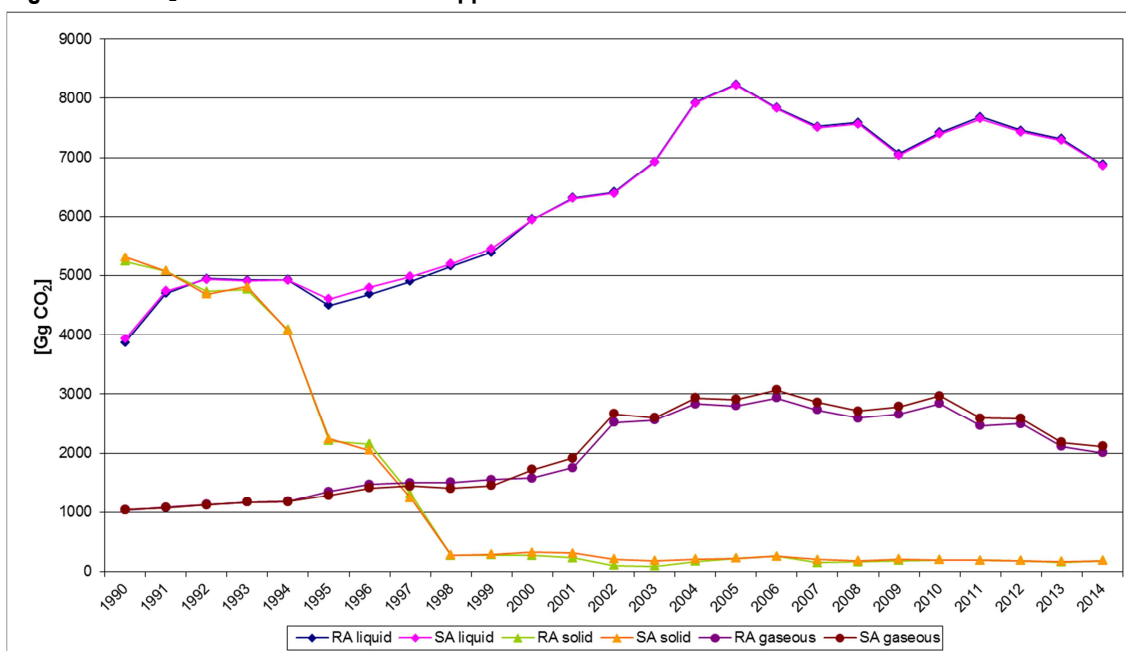


Table 3-7 – CO<sub>2</sub> emissions of reference and sectoral approach

CO <sub>2</sub> emissions of sectoral and reference approach										
[Gg CO <sub>2</sub> ]										
Year	Reference Approach					Sectoral Approach - 1 A Fuel Combustion				
	Solid	Liquid	Gaseous	Other	Total	Solid	Liquid	Gaseous	Other	Total
1990	5 241	3 871	1 039	33	10 183	5 317	3 932	1 039	33	10 327
1991	5 081	4 703	1 080	34	10 899	5 077	4 739	1 076	34	10 927
1992	4 733	4 952	1 128	35	10 848	4 686	4 936	1 123	35	10 780
1993	4 768	4 924	1 173	33	10 898	4 813	4 913	1 168	33	10 926
1994	4 092	4 933	1 184	32	10 242	4 073	4 923	1 177	32	10 206
1995	2 209	4 501	1 351	31	8 092	2 239	4 606	1 287	31	8 162
1996	2 155	4 690	1 472	24	8 342	2 043	4 803	1 411	24	8 281
1997	1 315	4 901	1 500	28	7 744	1 247	4 985	1 445	28	7 706
1998	272	5 159	1 506	54	6 992	280	5 200	1 409	65	6 954
1999	278	5 393	1 552	62	7 285	296	5 462	1 454	73	7 285
2000	274	5 953	1 580	60	7 867	325	5 948	1 722	77	8 071
2001	233	6 320	1 758	59	8 369	317	6 307	1 920	97	8 641
2002	108	6 412	2 519	60	9 099	215	6 393	2 669	104	9 381
2003	93	6 932	2 556	62	9 644	187	6 922	2 600	102	9 811
2004	170	7 928	2 837	71	11 005	213	7 917	2 938	114	11 183
2005	228	8 239	2 803	62	11 332	224	8 224	2 910	108	11 467
2006	264	7 845	2 937	68	11 113	260	7 831	3 069	118	11 278
2007	156	7 525	2 731	69	10 481	204	7 506	2 860	119	10 689
2008	165	7 592	2 594	72	10 423	186	7 567	2 714	128	10 596
2009	184	7 064	2 657	70	9 976	211	7 040	2 788	106	10 144
2010	202	7 422	2 841	62	10 527	199	7 398	2 970	114	10 680
2011	191	7 688	2 463	65	10 406	191	7 654	2 590	115	10 550
2012	184	7 454	2 499	64	10 201	185	7 427	2 587	115	10 314
2013	160	7 315	2 112	65	9 652	173	7 289	2 182	118	9 762
2014	183	6 887	2 004	62	9 137	186	6 867	2 114	114	9 280

Table 3-8 presents the difference of CO<sub>2</sub> emissions in percent between reference and sectoral approach.

**Table 3-8 – Difference of CO<sub>2</sub> emissions by type of fuel**

Difference of CO <sub>2</sub> emissions between sectoral and reference approach					
[%]					
Year	Solid	Liquid	Gaseous	Other	Total
1990	- 1.44	- 1.57	- 0.05	0.00	- 1.35
1991	0.08	- 0.76	0.42	0.00	- 0.25
1992	1.01	0.32	0.43	0.00	0.63
1993	- 0.93	0.23	0.42	0.00	- 0.26
1994	0.48	0.20	0.64	0.00	0.36
1995	- 1.33	- 2.27	5.01	0.00	- 0.86
1996	5.49	- 2.36	4.36	0.00	0.73
1997	5.41	- 1.69	3.79	0.00	0.49
1998	- 2.57	- 0.78	6.92	- 17.62	0.55
1999	- 6.04	- 1.27	6.76	- 15.41	0.00
2000	- 15.59	0.09	- 8.22	- 22.33	- 2.53
2001	- 26.48	0.20	- 8.45	- 38.77	- 3.14
2002	- 49.77	0.30	- 5.61	- 42.37	- 3.01
2003	- 50.12	0.14	- 1.67	- 39.39	- 1.71
2004	- 20.30	0.13	- 3.43	- 37.99	- 1.58
2005	1.59	0.19	- 3.70	- 42.92	- 1.18
2006	1.57	0.17	- 4.31	- 42.20	- 1.46
2007	- 23.63	0.26	- 4.51	- 41.86	- 1.94
2008	- 11.31	0.33	- 4.44	- 43.49	- 1.63
2009	- 12.45	0.34	- 4.67	- 33.82	- 1.66
2010	1.45	0.32	- 4.32	- 45.55	- 1.44
2011	- 0.23	0.43	- 4.90	- 43.44	- 1.36
2012	- 0.93	0.36	- 3.38	- 44.50	- 1.10
2013	- 7.35	0.36	- 3.22	- 44.67	- 1.12
2014	- 1.43	0.30	- 5.21	- 45.40	- 1.55

Source: Environment Agency

Note: Positive numbers indicate that CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> emissions between the two approaches is about 0.3%, which lies under the 2% significance threshold.
- Solid fuels: difference in CO<sub>2</sub> emissions between the two approaches is about -1.4%, which lies under the 2% significance threshold.
- Gaseous fuels: difference in CO<sub>2</sub> emissions between the two approaches is about -5.2%, meaning the sectoral approach is significantly higher than the significance level. The origin of this difference has mainly been identified within category 1A2f – *Manufacturing Industries and Construction - Non-Ferrous Minerals*. This category is composed of three dominating facilities, all covered under the emission trading scheme (ETS). However, the natural gas consumption as reported under ETS and as used in the sectoral approach is significantly higher as the one reported by the national energy balance used for the reference approach (see also first bullet above). The problem seems to lie in the national energy balance, in which the energy consumption of the category seems to be too low. Currently, discussions between the inventory team and the experts of the national statistics office are underway in order to resolve the issue for the next submission.
- Other Fossil Fuels: difference in CO<sub>2</sub> emissions between the two approaches is about -45%, meaning the sectoral approach is significantly higher than the significance level. The origin of this difference has been identified within category 1A2f – *Manufacturing Industries and Construction - Non-Ferrous Minerals*. 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 klinker 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, if the CO<sub>2</sub> emission of these secondary fossil fuels would be added to the reference approach, the difference between the two approaches would tend 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 2015v1.1 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 2015v1 → 2016v1	Type of revision
All fuels	AD was revised according to the revised energy balance and IEA Questionnaires as provided by STATEC	updated AD
carbon contents / other parameters	All parameters and carbon contents were revised, if necessary, according to the 2006 IPCC Guidelines.	updated parameters

### 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).
Consistency	Other fossil fuels: add CO <sub>2</sub> 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.

### 3.2.2 International Bunker Fuels

In 2014, GHG emissions from International Bunkers amounted to 1248 Gg CO<sub>2</sub>e (see Table 3-11), an increase of approximately 206% compared to 1990, which is mainly due to the increased international aviation activity.

**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 CO <sub>2</sub> eq
	Activity (GJ)	Total CO <sub>2</sub> eq	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Activity (GJ)	Total CO <sub>2</sub> eq	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	
1990	5 516 169	407.04	403.12	0.001	0.013	1 054	0.079	0.078	0.000007	0.000002	5 517 223
1991	5 765 550	425.44	421.35	0.001	0.014	1 139	0.085	0.084	0.000008	0.000002	5 766 689
1992	5 574 033	411.32	407.35	0.001	0.013	1 065	0.080	0.079	0.000007	0.000002	5 575 098
1993	5 512 762	406.79	402.87	0.001	0.013	1 430	0.107	0.106	0.000010	0.000003	5 514 192
1994	6 993 817	516.04	511.10	0.001	0.016	1 238	0.092	0.091	0.000009	0.000002	6 995 055
1995	7 927 783	584.97	579.36	0.002	0.019	1 246	0.093	0.092	0.000009	0.000002	7 929 029
1996	8 614 215	635.63	629.52	0.002	0.020	1 178	0.088	0.087	0.000008	0.000002	8 615 393
1997	10 305 632	760.42	753.13	0.002	0.024	1 139	0.085	0.084	0.000008	0.000002	10 306 771
1998	12 493 294	921.82	913.00	0.002	0.029	1 140	0.085	0.084	0.000008	0.000002	12 494 434
1999	14 095 591	1 040.09	1 030.10	0.003	0.033	1 252	0.093	0.092	0.000009	0.000003	14 096 843
2000	13 434 073	991.33	981.77	0.004	0.032	1 384	0.103	0.102	0.000010	0.000003	13 435 457
2001	14 530 054	1 072.20	1 061.86	0.004	0.034	1 387	0.103	0.102	0.000010	0.000003	14 531 440
2002	15 742 564	1 161.66	1 150.47	0.004	0.037	1 462	0.109	0.108	0.000010	0.000003	15 744 026
2003	16 399 902	1 210.17	1 198.51	0.004	0.039	1 490	0.111	0.110	0.000010	0.000003	16 401 392
2004	17 844 514	1 316.77	1 304.08	0.005	0.042	1 441	0.108	0.106	0.000010	0.000003	17 845 955
2005	18 131 067	1 337.96	1 325.03	0.005	0.043	1 933	0.144	0.143	0.000014	0.000004	18 132 999
2006	16 967 777	1 252.16	1 240.02	0.005	0.040	2 041	0.152	0.151	0.000014	0.000004	16 969 818
2007	18 238 604	1 345.90	1 332.89	0.005	0.043	1 699	0.127	0.126	0.000012	0.000003	18 240 303
2008	18 359 132	1 354.79	1 341.70	0.005	0.044	1 835	0.137	0.136	0.000013	0.000004	18 360 967
2009	17 588 864	1 297.93	1 285.40	0.005	0.042	1 471	0.110	0.109	0.000010	0.000003	17 590 334
2010	17 983 695	1 327.05	1 314.26	0.005	0.043	1 409	0.105	0.104	0.000010	0.000003	17 985 104
2011	16 887 889	1 246.22	1 234.18	0.005	0.040	1 734	0.129	0.128	0.000012	0.000003	16 889 623
2012	15 581 431	1 149.85	1 138.71	0.005	0.037	1 679	0.125	0.124	0.000012	0.000003	15 583 110
2013	15 659 460	1 155.61	1 144.41	0.005	0.037	1 391	0.104	0.103	0.000010	0.000003	15 660 851
2014	16 998 090	1 246.94	1 242.24	0.005	0.040	1 553	0.116	0.115	0.000011	0.000003	16 999 643
Trend 1990-2014	208.15%	206.34%	208.15%	261.16%	209.14%	47.30%	47.30%	47.30%	47.30%	47.30%	208.12%

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 are either originating from an airport outside of Luxembourg, or depart from Luxembourg with an international destination, which could be a small leisure airport in one of the neighbouring countries.<sup>85</sup> 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 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.

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<sup>85</sup> This oral communication has been documented internally by the energy expert (ARR 2011, §48).

- *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 2014						
Fuel	Flight Phase	CO <sub>2</sub>		CH <sub>4</sub>		N <sub>2</sub> O
		EF	(unit) type	EF	(unit) type	EF (unit) type
Jet Kerosene	LTO	2.600	(t/LTO) D	0.0001	(t/LTO) D	0.0001 (t/LTO) D
	cruise	3.15	(t/t fuel) D	0.00	(t/t fuel) D	0.0001 (t/t fuel) D
Aviation gasoline	all	69 300	(kg/TJ) D	0.50	(kg/TJ) D	2.00 (kg/TJ) D

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 2015v1 relevant to International Bunkers. For the quantitative aspect of these recalculations, please refer to Chapter 10.

**Table 3-13 – Recalculations for International Bunkers**

GHG source & sink category	Revisions 2015v1 → 2016v1	Type of revision
International Bunkers - Aviation	Activity data for Jet Kerosene for the years 2011 and 2013 was updated due to an update by the national statistics office to the energy balance. For 2011, the update resulted in a decrease of the consumption of 159 TJ and for 2013 in an increase of 7 TJ.	AD

#### 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 in order 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). A discrepancy, which has been observed for the year 2011, in submission 2014, for which the numbers from the energy balance are higher than the ones reported on the website of the national statistics office or by Eurostat (in the order of 160 TJ) has since been corrected. 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. These differences arise due to the fact that Eurostat and IEA round the national data to the next thousand unit (*i.e.* for the year 2014, Luxembourg had a kerosene consumption of 394.323 kt which is reported by Eurostat as 394.000 kt. When converted to energy units, the difference makes 14 TJ which account for 0.323 kt). If these rounding errors are taken into account, no discrepancies between inventory data and data published by Eurostat are observed.

The above explanation is also valid for aviation gasoline, because national consumption lies below 0.5 kt, hence resulting in a reported zero which, when converted to energy units obviously results again in a reported zero value (see Table 3-14).

**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
Aviation gasoline	kt	1	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
Kerosene type jet fuel	kt	128.000	184.000	312.000	337.000	365.000	380.000	414.000	420.000	394.000	423.000	425.000	408.000	417.000	392.000	361.000	363.000	394.000
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
Kerosene type jet fuel	TJ/kt or GJ/t	43.102	43.103	43.106	43.104	43.104	43.105	43.104	43.105	43.104	43.104	43.106	43.105	43.106	43.105	43.105	43.105	43.104
Source of data	Eurostat																	
Extracted on	08.03.16																	
Product	Unit	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
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	8.657
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
Source of data	STATEC																	
Extracted on	08.03.16																	
Product	Unit	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
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	0.199
Aviation gasoline	TJ	3.410	12.050	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	8.657
Aviation gasoline	TJ/kt or GJ/t	43.500	43.500	43.500	43.500	43.500	43.500	43.500	43.500	43.500	43.500	43.500	43.500	43.500	43.500	43.500	43.500	43.500
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
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
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
Source of data	GHG inventory submission 2016v1																	
Extracted on	08.03.16																	
Difference	Kerosene type	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Inventory/Eurostat	TJ	-1	-4	-16	3	9	19	-1	26	-16	5	38	1	8	-10	20	12	14
Inventory/Statec	TJ	NA	NA	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<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> 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 2015v1.

### **3.2.3.7 Planned improvements**

No further improvements are planned.

### **3.2.4 CO<sub>2</sub> capture from flue gases and subsequent CO<sub>2</sub> storage**

CO<sub>2</sub> capture from flue gases and CO<sub>2</sub> 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 where a detailed calculation model (NEMO) was used for non-CO<sub>2</sub> green house 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<sub>4</sub> and N<sub>2</sub>O in road transportation, 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 (2000-2013) 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.<sup>86</sup> These are mostly country-specific values, however, where 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 2014**

<b>Fuel Characteristics for 2014</b>						
<b>Country-specific Net Calorific Values and Densities</b>						
<b>Fuel</b>	<b>Net calorific value</b>			<b>Density</b>		
	<i>NCV</i>	<i>Unit</i>	<i>Source</i>	<i>Density</i>	<i>Unit</i>	<i>Source</i>
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 <sup>3</sup>	Statec			
Pellets	11.00	GJ/m <sup>3</sup>	Statec			
Wood chips	7.81	GJ/m <sup>3</sup>	Statec			
Biogaz	0.02	GJ/m <sup>3</sup>	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<sub>2</sub> emission factor for the combustion of blast furnace gas was determined based on emission measurement data and on the CO and CO<sub>2</sub> contents of blast furnace gas

<sup>86</sup> ARR 2010, § 21

produced in Luxembourg's blast furnaces in 1990.<sup>87</sup> 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<sub>2</sub>/TJ, was used for the years 1990 to 1997.

Similarly, a country-specific CO<sub>2</sub> emission factor for blast furnace gas lost in distribution or flared was determined: 245'323 kg CO<sub>2</sub>/TJ.

#### Natural Gas

In Luxembourg, one operator, CREOS S.A. (formerly SOTEG S.A.)<sup>88</sup>, 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<sup>3</sup>/h, respectively, one with Germany (Remich) with a capacity of 0.19 Mio Nm<sup>3</sup>/h and one with France (Esch/Alzette) with a capacity of 0.02 Mio Nm<sup>3</sup>/h.

For the calculation of the country-specific CO<sub>2</sub> 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<sub>2</sub> and N<sub>2</sub>) expressed in mol%;
- physical properties: density (kg/Nm<sup>3</sup>) and gross calorific value (GCV: MJ/Nm<sup>3</sup>);
- monthly import/consumption (Mio Nm<sup>3</sup>).<sup>89</sup>

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<sup>90</sup>.

From the monthly chemical composition, a monthly average "molecular" weight for natural gas (g/mol), "molecular" density (mol/Nm<sup>3</sup>) 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<sub>2</sub>/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<sub>2</sub> 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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<sup>87</sup> TÜV Rheinland, 1990, Bericht: 934/651014.

<sup>88</sup> <http://www.creos.lu>

<sup>89</sup> Nm<sup>3</sup> is defined at a pressure of 1035 mbar and 0 degree Celsius.

<sup>90</sup> 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, 2005-2014 (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: 1990-2014

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
EF (t CO <sub>2</sub> /TJ)	57.76	57.74	57.85	57.89	57.94	57.93	57.55	57.20	56.86	56.52
NCV (MJ/Nm <sup>3</sup> )	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 <sub>2</sub> /TJ)	56.22	56.26	56.40	56.53	56.67	56.91	57.01	56.79	56.66	57.06
NCV (MJ/Nm <sup>3</sup> )	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					
EF (t CO <sub>2</sub> /TJ)	56.71	56.99	56.79	56.68	56.76					
NCV (MJ/Nm <sup>3</sup> )	36.73	36.56	36.38	36.19	36.30					

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.<sup>91</sup> 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: 1990-2014 (tCO<sub>2</sub>/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	72.00	72.00	72.00	72.00	72.00	72.00	72.00	72.00	72.00	72.00
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	72.00	72.00	72.00	72.00	72.00	72.00	72.00	72.00	72.00	72.00
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					
Gas/Diesel Oil	73.87	73.86	73.86	73.86	73.87					
Motor Gasoline	72.00	72.00	72.00	72.00	72.00					
LPG	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<sub>2</sub> EF value for gasoline used by Belgium that in turn uses the IPCC default value. CO<sub>2</sub> 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 due to the fact that no data on the carbon content is available in Luxembourg, Luxembourg decided to revise its CO<sub>2</sub> emission factor for motor gasoline, based on the CO<sub>2</sub> emission factor of the two other neighbouring countries from which motor gasoline is imported. Indeed, as the Netherlands and Germany both use a CO<sub>2</sub> EF of 72 tCO<sub>2</sub>/TJ, Luxembourg decided to apply the same EF as a country-specific EF for the entire time series, to which the TERT agreed.

<sup>91</sup> ARR 2009, § 48

### **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<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions from combustion activities for electricity and heat production are reported, as well as CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O 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 2014, this source category was responsible for 7.70% of GHG emissions from fuel combustion activities (0.34% in 1990) and represented 6.70% of the national total GHG emissions in CO<sub>2</sub>e, excluding LULUCF (0.28% in 1990). Table 3-19 summarizes GHG emissions for category 1.A.1. - *Energy Industries*. Compared to 2013, GHG emissions increased by 5.1%. Since 2013, the electricity production level by the Twinerg gas turbine remained at a relatively low level, due to relatively low electricity prices.

With regard to CO<sub>2</sub> emissions, 1A1a - *Public electricity and heat production* is a key category, in 2014. It has been a key source for gaseous fuels since 2001 and for other fuels (MSW) from 1998 to 1999, in 2002, and from 2007 onwards: see Table 3-6 in Section 3.2.

Table 3-19 – GHG emission trends in CO<sub>2</sub>e category 1A1 –Energy Industries: 1990-2014

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 <sub>2</sub> eq	CO <sub>2</sub> (excl. biomass)	CH <sub>4</sub> (incl. biomass)	N <sub>2</sub> O (incl. biomass)	Total CO <sub>2</sub> eq	CO <sub>2</sub> (excl. biomass)	CH <sub>4</sub> (incl. biomass)	N <sub>2</sub> O (incl. biomass)	Total CO <sub>2</sub> eq	CO <sub>2</sub> (excl. biomass)	CH <sub>4</sub> (incl. biomass)	N <sub>2</sub> O (incl. biomass)
1990	35.64	33.29	0.036	0.005	NO	NO	NO	NO	NO	NO	NO	NO
1991	36.41	34.01	0.037	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	33.06	30.87	0.034	0.005	NO	NO	NO	NO	NO	NO	NO	NO
1996	26.45	24.76	0.026	0.003	NO	NO	NO	NO	NO	NO	NO	NO
1997	38.78	36.77	0.031	0.004	NO	NO	NO	NO	NO	NO	NO	NO
1998	69.48	67.01	0.038	0.005	NO	NO	NO	NO	NO	NO	NO	NO
1999	81.03	78.19	0.044	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	1 037.21	1 033.38	0.062	0.008	NO	NO	NO	NO	NO	NO	NO	NO
2004	1 261.58	1 257.24	0.070	0.009	NO	NO	NO	NO	NO	NO	NO	NO
2005	1 243.98	1 239.93	0.066	0.008	NO	NO	NO	NO	NO	NO	NO	NO
2006	1 308.02	1 303.70	0.070	0.009	NO	NO	NO	NO	NO	NO	NO	NO
2007	1 184.14	1 179.86	0.069	0.009	NO	NO	NO	NO	NO	NO	NO	NO
2008	999.75	995.52	0.068	0.009	NO	NO	NO	NO	NO	NO	NO	NO
2009	1 195.44	1 191.11	0.070	0.009	NO	NO	NO	NO	NO	NO	NO	NO
2010	1 207.30	1 203.27	0.065	0.008	NO	NO	NO	NO	NO	NO	NO	NO
2011	1 003.11	999.04	0.065	0.008	NO	NO	NO	NO	NO	NO	NO	NO
2012	1 039.49	1 035.44	0.065	0.008	NO	NO	NO	NO	NO	NO	NO	NO
2013	686.10	682.30	0.060	0.008	NO	NO	NO	NO	NO	NO	NO	NO
2014	721.42	717.70	0.059	0.008	NO	NO	NO	NO	NO	NO	NO	NO
<b>Trend 1990-2014</b>	1923.98%	2056.08%	62.79%	54.67%	NA	NA	NA	NA	NA	NA	NA	NA
<b>Trend 2013-2014</b>	5.15%	5.19%	-1.82%	-2.24%	NA	NA	NA	NA	NA	NA	NA	NA

Source: Environment Agency.

Notes: CH<sub>4</sub> emissions are converted in CO<sub>2</sub>e 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<sub>2</sub>O emissions are converted in CO<sub>2</sub>e 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<sup>92</sup>). 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 2002-2014, MSW fractions are calculated similarly based on the following waste composition analysis:

- 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;

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 fraction is calculated based on the following study:

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<sup>92</sup> For the different waste treatment schemes, see Chapter 8 on waste.

- Air & Noise Division of the Environment Agency, "Abschätzung emitTierter Klimagase durch die MBA Fridhaff abgeschiedene und verbrannte heizwertreiche Fraktion", Luxembourg, 2010

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: 1990-2014**

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	1 239 536	NO	NO	895 973	343 564
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	1 144 148	NO	NO	832 290	311 859
1996	904 412	900	14 026	648 213	241 274
1997	1 188 817	18 919	123 730	760 358	285 810
1998	1 492 852	30 783	190 255	687 092	584 722
1999	1 733 730	31 593	249 929	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	18 706 709	62 283	17 102 526	906 185	635 714
2004	22 634 832	66 616	20 850 220	984 754	733 241
2005	22 297 365	43 250	20 647 091	972 755	634 269
2006	23 401 589	39 936	21 624 432	1 034 178	703 044
2007	21 344 519	39 171	19 508 383	1 083 528	713 437
2008	18 159 491	65 639	16 205 838	1 137 014	750 999
2009	21 499 310	86 882	19 534 163	1 142 473	735 792
2010	21 919 884	33 053	20 082 942	1 155 510	648 378
2011	18 311 148	33 698	16 344 441	1 253 248	679 762
2012	19 030 087	28 975	17 071 478	1 264 300	665 334
2013	12 855 292	24 259	10 853 489	1 294 881	682 663
2014	13 543 405	20 520	11 521 006	1 351 249	650 630
<b>Trend 1990-2014</b>	1016.25%	NA	NA	54.08%	93.47%
<b>Trend 2013-2014</b>	5.35%	-15.41%	6.15%	4.35%	-4.69%

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<sub>2</sub> emissions on the basis of waste fractions (such as paper, wood, plastics) in the waste incinerated, as the following equation shows:

$$CO_2 \text{ emission} = MSW \cdot \sum_j (WF_j \cdot dm_j \cdot CF_j \cdot FCF_j \cdot OF_j) \cdot \frac{44}{12}$$

with:

CO <sub>2</sub> emissions	= CO <sub>2</sub> emissions in inventory year (Gg/yr)
MSW	= total amount of municipal solid waste as wet weight incinerated or open-burned (Gg/yr)
WF <sub>j</sub>	= fraction of waste type/material of component j in the MSW (as wet weight incinerated or open-burned)
dm <sub>j</sub>	= dry matter content in the component j of the MSW incinerated or open-burned (fraction)
CF <sub>j</sub>	= fraction of carbon in the dry matter ( <i>i.e.</i> , carbon content) of component j
FCF <sub>j</sub>	= fraction of fossil carbon in the total carbon of component j
OF <sub>j</sub>	= oxidation factor (fraction)
44/12	= molecular weight ratio M <sub>CO2</sub> (g/mol)/M <sub>C</sub> (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<sub>j</sub>, CF<sub>j</sub>, FCF<sub>j</sub> and OF<sub>j</sub> were taken.<sup>93</sup>

Reported CO<sub>2</sub> emissions of waste incineration are only CO<sub>2</sub> emissions from fossil MSW. However, the activity data includes both biogenic and fossil MSW fractions. This means that biogenic CO<sub>2</sub> 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).<sup>94</sup>

**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

<sup>93</sup> 2006 IPCC Guidelines, Vol. 5, Chap. 2, Tab. 2.4, p2.14

<sup>94</sup> Restabfallanalyse 2004/05 im Großherzogtum Luxemburg, Band 1: Kompendium, Luxembourg, 2005.

CH<sub>4</sub> emissions were estimated using 2006 IPCC Guidelines Tier 1 methodology. CH<sub>4</sub> 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<sub>4</sub> emissions are calculated according to the following equation:

$$CH_4 \text{ Emissions} = \text{Fuel Consumption}_{MSW} \bullet \text{Emission Factor}_{MSW}$$

with:

CH<sub>4</sub> Emissions = CH<sub>4</sub> emissions (kg GHG)

Fuel Consumption<sub>MSW</sub> = amount of incinerated MSW (TJ)

Emission Factor<sub>MSW</sub> = emission factor (kg gas/TJ)

The CH<sub>4</sub> 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<sub>2</sub>O emissions are calculated according to the following equation:

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

with:

N<sub>2</sub>O Emissions = N<sub>2</sub>O emissions in inventory year (Gg/yr)

IW<sub>i</sub> = amount of incinerated waste of type i (Gg/yr)

EF<sub>i</sub> = N<sub>2</sub>O emission factor (kg N<sub>2</sub>O /Gg of waste) for waste of type i

10<sup>-6</sup> = conversion from kilogram to gigagram

i = category or type of waste incinerated (MSW)

The N<sub>2</sub>O 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<sub>2</sub> emissions were not calculated using an emission factor, but instead, the calculation is based on the carbon content of the waste. CO<sub>2</sub> 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<sub>2</sub>, 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<sub>4</sub>, it is good practice to apply the CH<sub>4</sub> emission factors provided in Volume 2, Chapter 2 of the 2006 IPCC Guidelines. The CH<sub>4</sub> default emission factor of 30 kg CH<sub>4</sub>/TJ is applied.

For N<sub>2</sub>O, the default emission factor of 4.0 kg N<sub>2</sub>O/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<sub>2</sub>O/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 2014.

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

1A1a - Public Electricity & Heat Production Emission Factors for 2014 (kg/TJ)						
Fuel	Fuel Type	CO <sub>2</sub>		CH <sub>4</sub>		N <sub>2</sub> O
		EF	type	EF	type	EF
Gas Oil	liquid	73 862	CS	3.00	D	0.60
Natural Gas	gaseous	56 680	CS	1.00	D	0.10
Biogas	biomass	54 600	D	1.00	D	0.10
Wood & wood wastes	biomass	112 000	D	30.00	D	4.00
MSW (biogenic)	biomass	95 374	IEF	30.00	D	4.00
MSW (fossil)	other	95 702	IEF	30.00	D	4.00

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 <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
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	NO	NO	NO	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	73 850	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	94 719	28.00	3.73	97 396	30.00	4.00
2004	73 870	3.00	0.60	56 671	1.00	0.10	92 881	27.52	3.67	96 441	30.00	4.00
2005	73 882	3.00	0.60	56 910	1.00	0.10	92 988	26.64	3.55	97 300	30.00	4.00
2006	73 876	3.00	0.60	57 008	1.00	0.10	91 723	26.22	3.49	96 690	30.00	4.00
2007	73 862	3.00	0.60	56 793	1.00	0.10	91 508	25.95	3.46	96 753	30.00	4.00
2008	73 874	3.00	0.60	56 665	1.00	0.10	90 464	25.37	3.38	96 366	30.00	4.00
2009	73 867	3.00	0.60	57 056	1.00	0.10	88 486	24.40	3.25	95 344	30.00	4.00
2010	73 867	3.00	0.60	56 712	1.00	0.10	85 728	22.33	2.97	95 448	30.00	4.00
2011	73 859	3.00	0.60	56 988	1.00	0.10	86 581	22.74	3.02	95 787	30.00	4.00
2012	73 857	3.00	0.60	56 793	1.00	0.10	85 894	22.22	2.95	95 844	30.00	4.00
2013	73 862	3.00	0.60	56 680	1.00	0.10	86 111	22.35	2.97	95 702	30.00	4.00
2014	73 874	3.00	0.60	56 756	1.00	0.10	84 045	20.83	2.77	95 755	30.00	4.00

Source: Environment Agency.

The unique trend of the CO<sub>2</sub> 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<sub>2</sub> IEF between specific years correspond to the breaks in the composition of incinerated waste.

### 3.2.6.3 Uncertainties and time-series consistency

For uncertainties on activity data and emission factors, please refer to section 1.7.

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. Also, 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 (see also section 7.3 on solid waste disposal on land).

#### 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 3-24 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 3-24 – Recalculations done since submission 2015v1**

GHG source & sink category	Revisions 2015v1 → 2016v1	Type of revision
1A1a	Fuel consumption data for natural gas were revised for the years 1995-1999 resulting in a decrease of emissions by 50 to 92 Gg CO <sub>2</sub> and for the years 2002 to 2010 resulting in a decrease of 0.7 to 2.4 Gg CO <sub>2</sub> due to an error correction in a formula.	updated AD

#### 3.2.6.6 Category-specific planned improvements including those 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.

**Table 3-25 – Planned improvements for category 1.A.1. – Energy Industries**

GHG source & sink category	Planned improvement
1A1a - Public Electricity and Heat Production	waste incineration with energy recovery: implement new waste composition analysis for the year 2015.

### **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 2014, category *1A2 – Manufacturing Industries and Construction* was responsible for 11.65% of GHG emissions from fuel combustion activities (60.69% in 1990) and represented 10.13% of the total GHG emissions of Luxembourg, excluding LULUCF (49.0% in 1990). Compared to 2013, emissions of 1A2 decreased by 6.47%, mainly due to the onset of the less favourable economic situation, and the closure of several facilities in the iron & steel industry (*1A2a*).

Table 3-26 summarizes GHG emissions for *1A2 – Manufacturing Industries and Construction* and the relevant sub-categories.

With regard to CO<sub>2</sub> emissions, *1A2 – Manufacturing Industries and Construction* is a key category, in 2014 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 3-26 – GHG emission trends in CO<sub>2</sub>e for IPCC sub-category 1A2 – Fuel Combustion Activities – Manufacturing Industries and Construction: 1990-2014**

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 <sub>2</sub> eq	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Total CO <sub>2</sub> eq	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Total CO <sub>2</sub> eq	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Total CO <sub>2</sub> eq	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
1990	5 414.71	5 407.41	0.109	0.015	28.38	28.36	0.0005	0.0000	170.19	169.77	0.005	0.001	NO	IE	IE	IE
1991	5 154.12	5 147.10	0.104	0.015	29.43	29.41	0.0005	0.0000	186.63	186.09	0.007	0.001	NO	IE	IE	IE
1992	4 756.58	4 750.04	0.097	0.014	29.69	29.66	0.0005	0.0000	173.89	173.46	0.005	0.001	NO	IE	IE	IE
1993	4 928.14	4 921.12	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	4 070.40	4 064.55	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	2 320.89	2 317.65	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	2 106.97	2 103.98	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	1 339.62	1 337.76	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	341.40	341.00	0.007	0.001	41.45	41.41	0.0007	0.0001	209.48	209.23	0.004	0.000	27.64	27.61	0.0005	0.0001
2001	393.67	393.22	0.008	0.001	42.04	42.00	0.0007	0.0001	234.76	234.49	0.005	0.001	38.59	38.55	0.0007	0.0001
2002	375.25	374.83	0.007	0.001	40.36	40.32	0.0007	0.0001	231.14	230.88	0.004	0.001	42.11	42.06	0.0008	0.0001
2003	301.99	301.68	0.005	0.001	46.20	46.16	0.0008	0.0001	214.37	214.13	0.004	0.000	40.46	40.42	0.0007	0.0001
2004	388.79	388.39	0.007	0.001	52.65	52.60	0.0009	0.0001	214.85	214.61	0.004	0.000	34.58	34.54	0.0006	0.0001
2005	379.53	379.14	0.007	0.001	51.32	51.28	0.0009	0.0001	221.48	221.24	0.004	0.000	34.45	34.41	0.0006	0.0001
2006	464.09	463.63	0.008	0.001	56.45	56.39	0.0010	0.0001	206.15	205.94	0.004	0.000	26.03	26.01	0.0005	0.0000
2007	459.24	458.78	0.008	0.001	52.85	52.80	0.0009	0.0001	186.18	185.99	0.003	0.000	21.04	21.02	0.0004	0.0000
2008	446.70	446.26	0.008	0.001	51.37	51.32	0.0009	0.0001	180.84	180.65	0.003	0.000	26.81	26.79	0.0005	0.0000
2009	382.00	381.63	0.007	0.001	45.00	44.95	0.0008	0.0001	136.22	136.08	0.002	0.000	23.69	23.67	0.0004	0.0000
2010	445.69	445.25	0.008	0.001	52.95	52.90	0.0009	0.0001	161.41	161.24	0.003	0.000	17.09	17.08	0.0003	0.0000
2011	320.46	320.15	0.006	0.001	50.91	50.86	0.0009	0.0001	221.98	221.75	0.004	0.000	22.23	22.21	0.0004	0.0000
2012	342.70	342.37	0.006	0.001	51.42	51.37	0.0009	0.0001	173.03	172.83	0.003	0.000	12.32	12.31	0.0002	0.0000
2013	329.78	329.46	0.006	0.001	50.53	50.49	0.0009	0.0001	176.51	176.30	0.004	0.000	12.17	12.16	0.0002	0.0000
2014	271.00	270.73	0.005	0.000	49.36	49.31	0.0009	0.0001	141.67	141.50	0.003	0.000	10.31	10.30	0.0002	0.0000
Trend 1990-2014	-95.00%	-94.99%	-95.61%	-96.84%	73.89%	73.88%	88.05%	88.05%	-16.76%	-16.65%	-47.47%	-65.05%	NA	NA	NA	NA
Trend 2013-2014	-17.83%	-17.83%	-17.93%	-17.91%	-2.33%	-2.33%	-2.46%	-2.46%	-19.74%	-19.74%	-19.43%	-18.89%	-15.34%	-15.34%	-15.47%	-15.48%

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 <sub>2</sub> eq	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Total CO <sub>2</sub> eq	CO <sub>2</sub> (excl. biomass)	CH <sub>4</sub> (incl. biomass)	N <sub>2</sub> O (incl. biomass)	Total CO <sub>2</sub> eq	CO <sub>2</sub> (excl. biomass)	CH <sub>4</sub> (incl. biomass)	N <sub>2</sub> O (incl. biomass)	Total CO <sub>2</sub> eq	CO <sub>2</sub> (excl. biomass)	CH <sub>4</sub> (incl. biomass)	N <sub>2</sub> O (incl. biomass)
1990	8.18	8.16	0.000	0.000	539.06	536.51	0.037	0.005	146.29	137.42	0.007	0.029	6 306.82	6 150.22	0.152	0.022
1991	12.83	12.80	0.000	0.000	493.84	491.49	0.034	0.005	269.40	260.29	0.009	0.030	6 146.24	5 866.89	0.146	0.021
1992	12.50	12.48	0.000	0.000	538.08	535.45	0.038	0.006	310.36	299.45	0.010	0.036	5 821.11	5 501.09	0.142	0.021
1993	9.16	9.14	0.000	0.000	487.50	485.25	0.033	0.005	311.96	301.99	0.010	0.033	5 947.18	5 625.44	0.143	0.021
1994	12.12	12.09	0.000	0.000	591.20	588.24	0.043	0.006	317.72	307.50	0.011	0.033	5 227.41	4 900.36	0.136	0.020
1995	12.33	12.30	0.000	0.000	516.17	513.79	0.035	0.005	284.76	274.67	0.010	0.033	3 367.11	3 076.33	0.089	0.013
1996	10.88	10.86	0.000	0.000	544.28	541.70	0.038	0.006	305.09	294.15	0.013	0.036	3 225.85	2 914.75	0.089	0.013
1997	13.76	13.73	0.000	0.000	504.33	502.03	0.034	0.005	388.54	375.23	0.014	0.043	2 476.32	2 083.26	0.067	0.010
1998	12.88	12.85	0.000	0.000	467.18	464.71	0.036	0.005	412.87	398.11	0.014	0.048	1 436.96	1 020.96	0.047	0.007
1999	18.10	18.05	0.001	0.000	514.21	511.59	0.038	0.006	450.08	441.56	0.015	0.027	1 556.73	1 103.27	0.050	0.007
2000	39.27	39.21	0.001	0.000	532.12	529.19	0.043	0.006	261.77	253.00	0.011	0.029	1 453.13	1 187.66	0.056	0.008
2001	48.25	48.18	0.001	0.000	548.87	545.34	0.053	0.007	284.53	273.63	0.011	0.036	1 590.72	1 301.78	0.067	0.009
2002	49.13	49.06	0.001	0.000	453.22	450.18	0.046	0.006	326.18	309.58	0.011	0.055	1 517.40	1 187.33	0.060	0.008
2003	18.88	18.85	0.000	0.000	388.82	386.08	0.041	0.006	468.24	438.47	0.015	0.099	1 478.97	1 007.33	0.053	0.007
2004	17.73	17.70	0.000	0.000	445.17	442.03	0.047	0.007	465.10	436.62	0.014	0.094	1 618.87	1 149.87	0.061	0.008
2005	18.75	18.72	0.000	0.000	457.83	454.59	0.049	0.007	426.48	400.59	0.039	0.084	1 589.84	1 159.38	0.062	0.008
2006	13.82	13.80	0.000	0.000	494.78	491.15	0.055	0.008	395.09	372.49	0.037	0.073	1 656.41	1 256.91	0.068	0.009
2007	12.91	12.89	0.000	0.000	434.02	430.72	0.050	0.007	369.25	350.22	0.038	0.061	1 535.49	1 162.21	0.063	0.008
2008	14.20	14.18	0.000	0.000	418.36	415.12	0.049	0.007	319.05	304.41	0.037	0.046	1 457.33	1 134.33	0.062	0.008
2009	19.15	19.12	0.000	0.000	415.44	412.56	0.043	0.006	285.10	273.58	0.030	0.036	1 306.59	1 018.01	0.054	0.007
2010	16.52	16.50	0.000	0.000	410.98	407.75	0.049	0.007	316.49	304.09	0.034	0.039	1 421.13	1 100.71	0.061	0.008
2011	36.50	36.47	0.001	0.000	412.21	409.10	0.047	0.006	301.68	291.79	0.031	0.031	1 365.97	1 060.54	0.059	0.008
2012	13.94	13.93	0.000	0.000	402.16	399.06	0.047	0.006	245.77	238.11	0.027	0.023	1 241.34	991.86	0.058	0.008
2013	14.03	14.01	0.000	0.000	347.19	344.14	0.046	0.006	235.82	228.50	0.027	0.022	1 166.05	926.56	0.057	0.008
2014	11.86	11.84	0.000	0.000	392.90	389.77	0.047	0.007	213.54	206.43	0.031	0.021	1 090.64	873.45	0.056	0.008
Trend 1990-2014	44.94%	45.07%	4.98%	-20.66%	-27.11%	-27.35%	27.62%	20.56%	45.97%	50.22%	362.57%	-27.27%	-82.71%	-85.80%	-63.00%	-65.59%
Trend 2013-2014	-15.47%	-15.47%	-15.68%	-15.80%	13.17%	13.26%	2.82%	2.89%	-9.45%	-9.66%	16.13%	-4.80%	-6.47%	-5.73%	-0.93%	-0.18%

Source: Environment Agency.

Notes: CH<sub>4</sub> emissions are converted in CO<sub>2</sub>e 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<sub>2</sub>O emissions are converted in CO<sub>2</sub>e 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 2014, fuel combustion in iron and steel was responsible for 2.89% of GHG emissions from fuel combustion activities (this share was 52.1% in 1990) and represented 2.52% of the total GHG emissions in CO<sub>2</sub>e, excluding LULUCF (42.07% in 1990). Compared to 2013, emissions decreased by 17.8% and compared to 1990, by 95.0%.

#### 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<sub>2</sub> 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 3-27 gives a summary of which combustion activities are included for estimating GHG emissions pertaining to category *1A2a – Iron & Steel*.

**Table 3-27 – Iron and steel combustion activities included in the GHG inventory**

Combustion activity	SNAP <sup>95</sup> code

<sup>95</sup> Technology oriented Standardized Nomenclature for Air Pollutants (SNAP)

Combustion activity	SNAP <sup>95</sup> 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<sup>96</sup> 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.

#### 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

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<sup>96</sup> Later Arcelor-Arbed, and now Arcelor-Mittal.

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 Schiffflange were temporarily 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 3-28 gives a summary of the amount of energy used in category *1A2a – Iron and Steel*.

Table 3-28 – Activity data for category 1A2a – Iron and Steel: 1990-2014

1A2a - Iron & Steel						
Activity Data by fuel type (GJ)						
Year	Activity Total	Solid <i>Blast Furnace Gas, Coke Oven Coke, Coking Coke, Other Bituminous Coal</i>	Liquid <i>Residual Fuel Oil, Gas Oil</i>	Gaseous <i>Natural Gas</i>	Biomass	Other
1990	31 860 026	24 297 184	632 309	6 930 533	NO	NO
1991	29 890 062	23 212 906	1 082 023	5 595 133	NO	NO
1992	28 105 939	21 153 539	1 543 162	5 409 238	NO	NO
1993	29 095 910	22 278 448	1 368 941	5 448 521	NO	NO
1994	24 725 273	18 169 300	1 249 467	5 306 506	NO	NO
1995	16 203 419	9 509 657	650 277	6 043 485	NO	NO
1996	15 440 760	8 471 037	559 065	6 410 658	NO	NO
1997	11 485 816	4 700 381	505 079	6 280 357	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	5 952 604	NO	360 167	5 592 437	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	5 308 449	NO	91 251	5 217 198	NO	NO
2004	6 806 743	NO	153 569	6 653 174	NO	NO
2005	6 631 230	NO	103 627	6 527 604	NO	NO
2006	8 109 012	NO	79 708	8 029 304	NO	NO
2007	8 058 654	NO	64 889	7 993 765	NO	NO
2008	7 862 277	NO	43 438	7 818 840	NO	NO
2009	6 679 554	NO	30 926	6 648 628	NO	NO
2010	7 828 273	NO	75 512	7 752 762	NO	NO
2011	5 608 156	NO	32 621	5 575 535	NO	NO
2012	6 024 672	NO	12 569	6 012 103	NO	NO
2013	5 807 079	NO	18 279	5 788 800	NO	NO
2014	4 765 470	NO	15 320	4 750 150	NO	NO
<b>Trend 1990-2014</b>	-85.04%	NA	-97.58%	-31.46%	NA	NA
<b>Trend 2013-2014</b>	-17.94%	NA	-16.19%	-17.94%	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 3-29).

For blast furnace gas combusted in blast furnaces or combustion plants, a plant specific CO<sub>2</sub> 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<sub>4</sub> and N<sub>2</sub>O emission factors are default values from the 2006 IPCC Guidelines. The CO<sub>2</sub> EF for BFG lost in distribution and flaring is also plant specific and was based on measurements and BFG composition.<sup>87</sup> 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<sub>2</sub> in the atmosphere. Therefore, the same emission factor as for flaring was used. No default values for CH<sub>4</sub> and N<sub>2</sub>O 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 3-29 gives an overview of the different emission factors used in this submission.

**Table 3-29 – Emission factors for category 1A2a – Iron and Steel**

1A2a Iron & Steel						
Emission Factors for 2014 (kg/TJ)						
Fuel	Fuel Type	CO <sub>2</sub>		CH <sub>4</sub>		N <sub>2</sub> O
		EF	type	EF	type	EF type
Blast furnace gas	solid	257 181	PS, CS	1.00	D	0.10 D
BFG (DistLoss&Flar)	solid	245 323	PS, CS	1.00	D	0.10 D
Coke Oven Coke	solid	107 000	D	10.00	D	1.50 D
Other Bituminous Coal	solid	94 600	D	10.00	D	1.50 D
Coking Coke	solid	94 600	D	10.00	D	1.50 D
Residual Fuel Oil	liquid	77 400	D	3.00	D	0.60 D
Gas Oil	liquid	73 862	CS	3.00	D	0.60 D
Natural Gas	gaseous	56 793	CS	1.00	D	0.10 D

Source: Environment Agency.

Table 3-30 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<sub>2</sub> 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<sub>2</sub> 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 3-30 – Implied emission factors for IPCC sub-category 1A2a – Iron and Steel**

1A2a Iron & Steel								
Implied Emission Factors (kg/TJ)								
Year	Solid			Liquid			Gaseous	
	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	N <sub>2</sub> O
1990	204 087	4.13	0.59	76 542	3.00	0.60	57 755	1.00
1991	204 235	4.11	0.58	76 830	3.00	0.60	57 743	1.00
1992	204 137	4.11	0.58	77 053	3.00	0.60	57 848	1.00
1993	202 008	4.24	0.60	76 891	3.00	0.60	57 894	1.00
1994	201 498	4.27	0.61	76 839	3.00	0.60	57 940	1.00
1995	201 690	4.27	0.61	76 201	3.00	0.60	57 929	1.00
1996	199 816	4.37	0.62	75 874	3.00	0.60	57 546	1.00
1997	200 038	4.37	0.62	75 706	3.00	0.60	57 205	1.00
1998	NO	NO	NO	75 530	3.00	0.60	56 863	1.00
1999	NO	NO	NO	74 789	3.00	0.60	56 522	1.00
2000	NO	NO	NO	73 827	3.00	0.60	56 221	1.00
2001	NO	NO	NO	73 825	3.00	0.60	56 258	1.00
2002	NO	NO	NO	73 825	3.00	0.60	56 396	1.00
2003	NO	NO	NO	73 844	3.00	0.60	56 533	1.00
2004	NO	NO	NO	73 870	3.00	0.60	56 671	1.00
2005	NO	NO	NO	73 882	3.00	0.60	56 910	1.00
2006	NO	NO	NO	73 876	3.00	0.60	57 008	1.00
2007	NO	NO	NO	73 862	3.00	0.60	56 793	1.00
2008	NO	NO	NO	73 874	3.00	0.60	56 665	1.00
2009	NO	NO	NO	73 867	3.00	0.60	57 056	1.00
2010	NO	NO	NO	73 867	3.00	0.60	56 712	1.00
2011	NO	NO	NO	73 859	3.00	0.60	56 988	1.00
2012	NO	NO	NO	73 857	3.00	0.60	56 793	1.00
2013	NO	NO	NO	73 862	3.00	0.60	56 680	1.00
2014	NO	NO	NO	73 874	3.00	0.60	56 756	1.00

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 2014, fuel combustion due to non-ferrous metal production was responsible for 0.53% of GHG emissions from fuel combustion activities (0.27% in 1990) and represented 0.46% of the national total GHG emissions in CO<sub>2</sub>e, excluding LULUCF (0.22% in 1990). Compared to 2013, emissions decreased by 2.33% and compared to 1990, they increased by 73.9%.

#### 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 3-31.

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 3-31 - Activity data for category 1A2b - Non-Ferrous Metals: 1990-2014**

<b>1A2b - Non-Ferrous Metals</b>						
<b>Activity Data by fuel type (GJ)</b>						
<b>Year</b>	<b>Activity Total</b>	<b>Solid</b>	<b>Liquid LPG</b>	<b>Gaseous Natural Gas</b>	<b>Biomass</b>	<b>Other</b>
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
<b>Trend 1990-2014</b>	88.05%	NA	NA	274.48%	NA	NA
<b>Trend 2013-2014</b>	-2.46%	NA	NA	-2.46%	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<sub>2</sub> from LPG and natural gas were used. Default EFs from the 2006 IPCC Guidelines have been applied for CH<sub>4</sub> and N<sub>2</sub>O (Table 3-32).

**Table 3-32 – Emission factors for category 1A2b – Non-Ferrous Metals**

1A2b - Non-Ferrous Metals Emission Factors for 2014 (kg/TJ)								
Fuel	Fuel Type	CO <sub>2</sub>		CH <sub>4</sub>		N <sub>2</sub> O		Source
		EF	type	EF	type	EF	type	
LPG	liquid	64 933	CS	1.00	D	0.10	D	AEV 2006 IPCC GL
Natural Gas	gaseous	56 680	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 2014, fuel combustion from the chemical industry was responsible for 1.11% of GHG emissions from fuel combustion activities (1.64% in 1990) and represented 1.34% of the national total GHG emissions, excluding LULUCF (1.32% in 1990). Compared to 2013, emissions decreased by 19.74% and compared to 1990, by 16.76%, mainly due to a lower natural gas consumption in 2014, following the phase out of one of the gas turbines.

#### 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 (2000-2014) 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 3-33.

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.<sup>97</sup> 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 3-33- Activity data for category 1A2c - Chemicals: 1990-2014**

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	3 653 124	NO	218 707	3 434 417	NO	NO
2001	4 088 892	NO	253 681	3 835 211	NO	NO
2002	4 025 656	NO	220 952	3 804 704	NO	NO
2003	3 735 516	NO	170 242	3 565 274	NO	NO
2004	3 727 063	NO	197 211	3 529 852	NO	NO
2005	3 835 562	NO	174 153	3 661 408	NO	NO
2006	3 587 922	NO	82 726	3 505 195	NO	NO
2007	3 254 793	NO	66 911	3 187 883	NO	NO
2008	3 174 955	NO	43 290	3 131 665	NO	NO
2009	2 373 939	NO	37 602	2 336 338	NO	NO
2010	2 820 404	NO	74 942	2 745 462	NO	NO
2011	3 870 246	NO	70 762	3 799 485	NO	NO
2012	2 993 329	NO	165 874	2 827 456	NO	NO
2013	3 039 817	NO	233 058	2 806 759	NO	NO
2014	2 434 192	NO	195 333	2 238 860	NO	NO
<b>Trend 1990-2014</b>	-0.88%	NA	-86.63%	125.07%	NA	NA
<b>Trend 2013-2014</b>	-19.92%	NA	-16.19%	-20.23%	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.

#### 3.2.7.4.2.3 Emission factors

The 2006 IPCC Guidelines default EFs have been applied for CO<sub>2</sub> for residual fuel oil, whereas for gas oil and natural gas country-specific EFs were used. Default EFs have been applied for CH<sub>4</sub> and N<sub>2</sub>O (Table 3-34).

<sup>97</sup> ARR 2009, § 61.



In 2014, fuel combustion from the paper and print industry was responsible for 0.11% of GHG emissions from fuel combustion activities and represented 0.10% of the national total GHG emissions in CO<sub>2</sub>e, excluding LULUCF. Compared to 2013, emissions decreased by 15.34%, due to a lower consumption of natural gas.

### 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 2000-2014. 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 3-36.

**Table 3-36- Activity data for category 1A2d - Pulp, Paper and Print: 1990-2014**

1A2d - Pulp, Paper & Print						
Activity Data by fuel type (GJ)						
Year	Activity Total	Solid	Liquid Gas Oil, Diesel Oil	Gaseous Natural Gas	Biomass	Other
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	484 892	NO	19 980	464 912	NO	NO
2001	675 967	NO	29 781	646 186	NO	NO
2002	736 418	NO	30 456	705 962	NO	NO
2003	709 519	NO	17 956	691 563	NO	NO
2004	603 315	NO	20 482	582 833	NO	NO
2005	600 296	NO	14 804	585 492	NO	NO
2006	454 264	NO	6 580	447 684	NO	NO
2007	368 720	NO	4 379	364 341	NO	NO
2008	471 724	NO	3 210	468 514	NO	NO
2009	414 095	NO	2 327	411 768	NO	NO
2010	299 920	NO	3 932	295 988	NO	NO
2011	389 307	NO	1 342	387 965	NO	NO
2012	216 340	NO	1 217	215 122	NO	NO
2013	214 081	NO	1 629	212 452	NO	NO
2014	180 995	NO	1 366	179 630	NO	NO
<b>Trend 1990-2014</b>	NA	NA	NA	NA	NA	NA
<b>Trend 2013-2014</b>	-15.45%	NA	-16.19%	-15.45%	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.



In 2014, fuel combustion from the food processing, beverages and tobacco industry was responsible for 0.13% of GHG emissions from fuel combustion activities (0.08% in 1990) and represented 0.11% of the national total GHG emissions excluding LULUCF (0.06% in 1990). Compared to 2013, emissions decreased by 15.5% and compared to 1990, increased by 44.9%.

#### 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 (2000-2014) 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 3-39.

**Table 3-39- Activity data for category 1A2e - Food Processing, Beverages and Tobacco: 1990-2014**

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	666 786	NO	97 766	569 020	NO	NO
2001	817 813	NO	123 547	694 266	NO	NO
2002	832 890	NO	119 963	712 928	NO	NO
2003	313 856	NO	64 125	249 731	NO	NO
2004	291 308	NO	69 246	222 062	NO	NO
2005	310 994	NO	59 979	251 016	NO	NO
2006	233 475	NO	29 092	204 382	NO	NO
2007	219 974	NO	23 453	196 521	NO	NO
2008	244 031	NO	20 580	223 451	NO	NO
2009	319 391	NO	53 165	266 226	NO	NO
2010	281 509	NO	30 903	250 607	NO	NO
2011	634 251	NO	18 993	615 258	NO	NO
2012	238 741	NO	21 476	217 264	NO	NO
2013	237 957	NO	30 537	207 420	NO	NO
2014	200 969	NO	25 594	175 375	NO	NO
<b>Trend 1990-2014</b>	62.15%	NA	-55.97%	166.48%	NA	NA
<b>Trend 2013-2014</b>	-15.54%	NA	-16.19%	-15.45%	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<sub>2</sub> from residual fuel oil, whereas for gasoil and natural gas country specific EFs were used. Default EFs have been applied for CH<sub>4</sub> and N<sub>2</sub>O (Table 3-40).

**Table 3-40 – Emission factors for category 1A2e – Food Processing, Beverages and Tobacco**

1A2e - Food Processing, Beverages & Tobacco						
Emission Factors for 2014 (kg/TJ)						
Fuel	Fuel Type	CO <sub>2</sub>		CH <sub>4</sub>		N <sub>2</sub> O
		EF	type	EF	type	EF
Residual Fuel Oil	liquid	77 400	D	3.00	D	0.60
Gas Oil	liquid	73 862	CS	3.00	D	0.60
Natural Gas	gaseous	56 680	CS	1.00	D	0.10

Source: Environment Agency

Table 3-41 gives an overview of the evolution of the implied emission factors per fuel type.

**Table 3-41 – 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 <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
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	74 099	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	73 857	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

Source: Environment Agency

The higher CO<sub>2</sub> 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 2014, fuel combustion emissions reported under 1A2f – *Non-metallic minerals* were responsible for 4.20% of GHG emissions from fuel combustion activities (this share was 5.19% in 1990) and represented 3.65% of the national total GHG emissions excluding LULUCF (4.19% in 1990). Compared to 2013, emissions increased by 13.2% and compared to 1990, decreased by 27.1%.

#### 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 3-46):

**Table 3-42 – Combustion activities included in 1A2f – Non-metallic minerals**

Description	SNAP code
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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 3-47.



**Table 3-43 – Activity data by fuel type of category 1A2f – Non-metallic minerals: 1990-2014**

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	4 864 379	1 793 790	170 106	2 900 483	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	5 350 666	1 989 234	133 697	3 227 734	313 212	572 010
2008	5 107 955	1 805 356	100 434	3 202 164	270 238	649 169
2009	5 247 041	2 043 207	37 557	3 166 278	218 574	433 991
2010	5 030 045	1 855 755	23 877	3 150 413	301 932	601 195
2011	5 091 632	1 819 386	29 527	3 242 719	274 250	576 457
2012	4 956 495	1 742 721	32 119	3 181 655	282 003	591 243
2013	4 023 463	1 657 980	27 785	2 337 698	292 689	613 050
2014	4 742 409	1 792 071	57 737	2 892 600	277 558	605 407
<b>Trend 1990-2014</b>	-33.23%	-45.74%	-81.79%	-16.95%	NA	NA
<b>Trend 2013-2014</b>	17.87%	8.09%	107.80%	23.74%	-5.17%	-1.25%

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<sub>2</sub> 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."<sup>98</sup> and "Aliapur"<sup>99</sup> on the use of tires as secondary fuels.

<sup>98</sup> [http://www.vdz-online.de/fileadmin/gruppen/vdz/3LiteraturRecherche/Taetigkeitsbericht07/VDZ\\_Kap\\_II.pdf](http://www.vdz-online.de/fileadmin/gruppen/vdz/3LiteraturRecherche/Taetigkeitsbericht07/VDZ_Kap_II.pdf)

<sup>99</sup> [http://www.aliapur.fr/media/files/RetD\\_new/Conferences\\_Publications/Pneus\\_usages\\_comme\\_combustible\\_alternatif\\_extrait.pdf](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<sup>100</sup>.

#### 3.2.7.7.2.3 Emission factors

The 2006 IPCC Guidelines default CO<sub>2</sub> 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<sub>4</sub> and N<sub>2</sub>O (Table 3-48).

**Table 3-44 – Emission factors for category 1A2f – Non-metallic minerals**

1A2f - Non-Metallic Minerals								
Emission Factors for 2014 (kg/TJ)								
Fuel	Fuel Type	CO <sub>2</sub>		CH <sub>4</sub>		N <sub>2</sub> O		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	73 862	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	56 680	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	81 300	PS	30.00	D	4.00	D	ETS 2006 IPCC GL

Source: Environment Agency

Table 3-49 gives an overview of the evolution of the implied emission factors per fuel type.

The increase of the CO<sub>2</sub> IEF of biomass from 2002 onwards is due to the use of different types of biomass over time. Indeed, tires (CO<sub>2</sub> EF: 88.00 t CO<sub>2</sub>/TJ) are used since 1998 as secondary fuel in the clinker production. Since 2002, sewage sludge (CO<sub>2</sub> EF: 100.00 t CO<sub>2</sub>/TJ) and since 2006, fluff, (CO<sub>2</sub> EF: 80.12 t CO<sub>2</sub>/TJ) are co-incinerated in the clinker production.

<sup>100</sup> [http://ec.europa.eu/clima/policies/ets/monitoring/index\\_en.htm](http://ec.europa.eu/clima/policies/ets/monitoring/index_en.htm)

**Table 3-45 – Implied emission factors for category 1A2f – Non-metallic minerals**

1A2f - Non-Metallic Minerals Implied Emission Factors (kg/TJ)															
Year	Solid			Liquid			Gaseous			Biomass			Other		
	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
1990	94 600	10.00	1.50	72 357	2.18	0.40	57 755	1.00	0.10	NO	NO	NO	NO	NO	NO
1991	94 600	10.00	1.50	72 436	2.46	0.46	57 743	1.00	0.10	NO	NO	NO	NO	NO	NO
1992	94 600	10.00	1.50	72 254	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	72 740	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	73 857	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

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 2014, fuel combustion emissions reported under 1A2g - *Other* manufacturing industries and construction were responsible for 2.28% of GHG emissions from fuel combustion activities (this share was 1.41% in 1990) and represented 1.98% of the national total GHG emissions excluding LULUCF (1.1% in 1990). Compared to 2013, emissions decreased by 9.45% and compared to 1990, increased by 45.97%.

#### 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 3-46):

**Table 3-46 – 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 on the consumption of diesel oil and gasoline used in these sources were derived from the national statistics institute (STATEC).

The activity data described here is the data reported by the operators to the Environment Agency through the annual reporting obligation in their operational permits. This bottom-up data combined with the bottom-up data which could not be matched with the top-down data elsewhere (1A2b - *Non-Ferrous Metals*: natural gas and LPG; 1A2c - *Chemicals*: natural gas; 1A2e - *Food Processing, Beverages and Tobacco*: natural gas from 1990-1999) was then matched with the top-down data from the national statistics institute (STATEC). To avoid double counting, the bottom-up data was subtracted from the top-down data. Activity data for other manufacturing industry and construction are listed in Table 3-47.

Table 3-47 – Activity data by fuel type of category 1A2g – Other: 1990-2014

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	1 884 738	1 083 597	206 140	182 270	412 732	NO	NO
1991	3 974 422	1 095 825	199 769	293 602	2 385 225	NO	NO
1992	4 591 191	1 318 174	217 880	251 723	2 803 414	NO	NO
1993	4 709 984	1 203 372	161 445	225 392	3 119 774	NO	NO
1994	4 683 088	1 208 240	320 437	251 136	2 903 275	NO	NO
1995	4 218 727	1 218 805	160 119	264 601	2 575 201	NO	NO
1996	4 493 974	1 334 353	254 976	219 399	2 685 246	NO	NO
1997	5 875 531	1 595 296	225 135	220 194	3 834 907	NO	NO
1998	6 251 652	1 732 840	183 946	426 505	3 908 361	NO	NO
1999	6 930 955	958 885	218 107	1 635 114	4 118 849	NO	NO
2000	3 821 413	1 009 559	232 377	801 097	1 778 380	NO	NO
2001	4 136 901	1 236 752	168 958	863 498	1 867 693	NO	NO
2002	4 593 258	1 899 427	138 204	845 872	1 709 755	NO	NO
2003	6 299 762	3 584 321	145 892	1 036 539	1 533 012	NO	NO
2004	6 270 456	3 685 268	147 911	853 453	1 583 824	NO	NO
2005	5 768 563	3 371 046	144 819	695 017	1 557 681	880 933	NO
2006	5 393 461	3 209 791	136 831	428 423	1 618 416	856 579	NO
2007	5 142 037	3 121 609	142 414	455 036	1 422 979	918 261	NO
2008	4 485 516	2 604 662	139 665	426 279	1 314 909	979 662	NO
2009	4 006 690	2 251 114	156 912	374 630	1 224 033	754 820	NO
2010	4 363 556	2 644 589	211 674	413 092	1 094 201	863 371	NO
2011	4 320 672	2 306 336	171 154	250 721	1 592 461	785 914	NO
2012	3 494 352	1 848 592	191 369	238 620	1 215 771	682 906	NO
2013	3 390 392	1 824 785	135 996	226 834	1 202 777	715 237	NO
2014	3 042 650	1 663 078	147 760	196 035	1 035 776	872 512	NO
<b>Trend 1990-2014</b>	61.44%	53.48%	-28.32%	7.55%	150.96%	NA	NA
<b>Trend 2013-2014</b>	-10.26%	-8.86%	8.65%	-13.58%	-13.88%	21.99%	NA

Source: Environment Agency

### 3.2.7.8.2.2 Methodological choices

For CO<sub>2</sub>, 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<sub>4</sub> and N<sub>2</sub>O from stationary combustion, the 2006 IPCC Guidelines Tier 1 approach has been applied for all fuels.

For CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O 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<sub>2</sub> 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<sub>4</sub> and N<sub>2</sub>O.

For mobile combustion (diesel oil and motor gasoline), country-specific values, derived from the GEORG model, have been applied for CH<sub>4</sub> and N<sub>2</sub>O (Table 3-48).

**Table 3-48 – Emission factors for category 1A2g – Other**

1A2g - Other								
Emission Factors for 2014 (kg/TJ)								
Fuel	Fuel Type	CO <sub>2</sub>		CH <sub>4</sub>		N <sub>2</sub> O		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	73 874	CS	3.00	D	0.60	D	AEV 2006 IPCC GL
Diesel Oil	liquid	71 408	CS	1.30	CS	10.40	CS	AEV
Gasoline	liquid	72 000	CS	28.00	CS	1.70	CS	AEV
LPG	liquid	64 933	CS	1.00	D	0.10	D	AEV 2006 IPCC GL
Natural Gas	gaseous	56 756	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

Table 3-49 gives an overview of the evolution of the implied emission factors for liquid fuels used by off-road vehicles and other machinery.

**Table 3-49 – 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 <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
1990	73 871	3.48	26.50
1991	73 885	3.47	26.53
1992	73 910	3.46	26.56
1993	73 870	3.45	26.57
1994	73 846	3.40	26.88
1995	73 777	4.32	26.56
1996	73 732	5.08	26.14
1997	73 750	4.71	26.72
1998	73 765	4.47	27.40
1999	73 688	5.42	26.93
2000	73 672	5.20	27.46
2001	73 697	4.71	28.19
2002	73 783	3.23	28.48
2003	73 822	2.69	27.32
2004	73 823	2.48	25.41
2005	73 834	2.36	23.56
2006	73 829	2.21	21.44
2007	71 799	2.01	18.10
2008	71 872	1.53	16.00
2009	71 811	1.48	14.51
2010	71 966	1.42	13.09
2011	71 777	1.36	11.66
2012	71 699	1.33	10.91
2013	71 408	1.30	10.40
2014	71 408	1.30	10.40

Source: Environment Agency

Table 3-50 gives an overview of the evolution of the implied emission factors for fuels used in stationary combustion by other manufacturing industries.

**Table 3-50 – 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 <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
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	75 505	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	73 850	3.00	0.60	57 205	1.00	0.10	NO	NO	NO
1998	97 401	10.00	1.50	70 640	2.28	0.42	56 863	1.00	0.10	NO	NO	NO
1999	97 445	10.00	1.50	71 457	2.44	0.46	56 522	1.00	0.10	NO	NO	NO
2000	97 500	10.00	1.50	69 887	1.95	0.34	56 221	1.00	0.10	NO	NO	NO
2001	97 500	10.00	1.50	70 575	2.08	0.37	56 258	1.00	0.10	NO	NO	NO
2002	97 500	10.00	1.50	70 380	2.05	0.36	56 396	1.00	0.10	NO	NO	NO
2003	97 500	10.00	1.50	70 402	2.12	0.38	56 533	1.00	0.10	NO	NO	NO
2004	97 500	10.00	1.50	70 748	2.24	0.41	56 671	1.00	0.10	NO	NO	NO
2005	97 500	10.00	1.50	70 388	2.19	0.40	56 910	1.00	0.10	112 000	30.00	4.00
2006	97 500	10.00	1.50	69 807	2.09	0.37	57 008	1.00	0.10	112 000	30.00	4.00
2007	97 500	10.00	1.50	68 996	1.91	0.33	56 793	1.00	0.10	112 000	30.00	4.00
2008	97 500	10.00	1.50	68 216	1.73	0.28	56 665	1.00	0.10	112 000	30.00	4.00
2009	97 500	10.00	1.50	71 507	2.26	0.41	57 056	1.00	0.10	112 000	30.00	4.00
2010	97 500	10.00	1.50	75 227	2.99	0.60	56 712	1.00	0.10	112 000	30.00	4.00
2011	97 500	10.00	1.50	75 020	3.00	0.60	56 988	1.00	0.10	112 000	30.00	4.00
2012	97 500	10.00	1.50	74 871	3.00	0.60	56 793	1.00	0.10	112 000	30.00	4.00
2013	97 500	10.00	1.50	73 917	3.00	0.60	56 680	1.00	0.10	112 000	30.00	4.00
2014	97 500	10.00	1.50	73 885	2.99	0.60	56 756	1.00	0.10	112 000	30.00	4.00

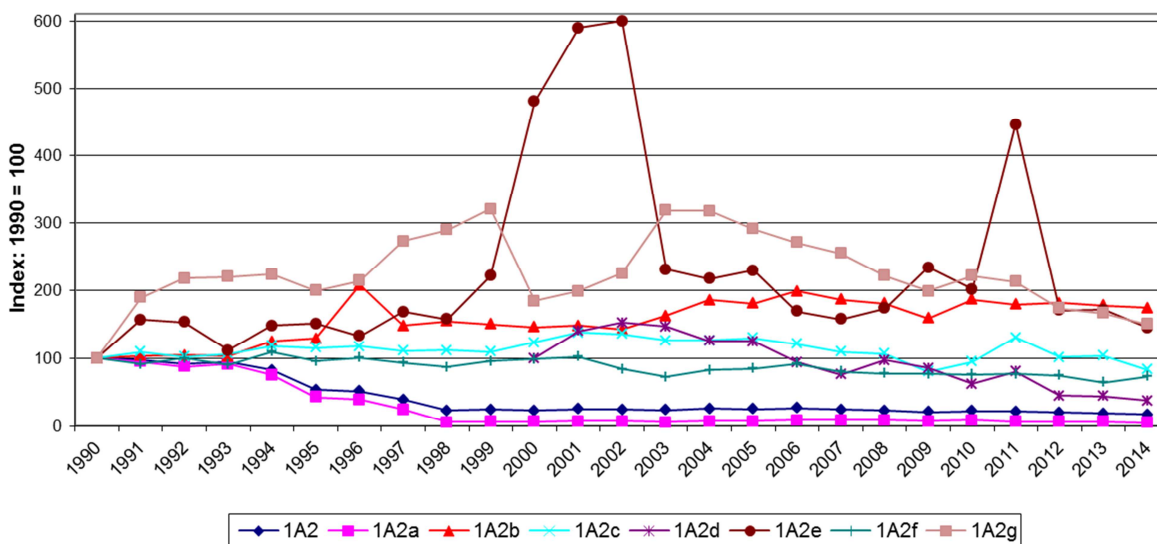
Source: Environment Agency

### 3.2.7.9 Uncertainties and time-series consistency

For uncertainties on activity data and emission factors, please refer to section 1.7.

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*: 1990-2014**



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 3-51 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, please refer to Chapter 10.

**Table 3-51 – Recalculations done since submission 2015v1**

GHG source & sink category	Revisions 2015v1 → 2016v1	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
1.A.2.g.vii	Emission calculation for off-road vehicles and other machinery was changed to a T3 methodology using the GEORG model, leading to lower emissions than in previous submissions where T1 default EFs were used.	Updated methodology and EF

### **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 3-52 will be explored.

**Table 3-52 – 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 emissions resulting from fuel combustion activities in the transport sector.

The 2016 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 2014, this source category was responsible for 65.10% of GHG emissions from fuel combustion activities (this share was only 25.87% in 1990) and represented 56.61% of the national total GHG emissions excluding LULUCF (coming from 20.89% in 1990). Compared to 2013, emissions decreased by 4.32% and compared to 1990 they increased by 126.79%.

Table 3-53 summarizes GHG emissions for IPCC Sub-category 1A3.

Table 3-53 – GHG emission trends in CO<sub>2</sub>e for IPCC sub-category 1A3 – Transport: 1990-2014

Year	1A3a - Civil Aviation				1A3b - Road Transportation				1A3c - Railways			
	Total CO <sub>2</sub> eq	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Total CO <sub>2</sub> eq	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Total CO <sub>2</sub> eq	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
1990	0.21	0.21	0.000002	0.00001	2 659.14	2 631.66	0.46	0.05	27.61	0.001	0.001	0.010
1991	0.33	0.32	0.000002	0.00001	3 161.80	3 129.17	0.51	0.07	27.61	0.001	0.001	0.010
1992	0.46	0.46	0.000003	0.00001	3 454.44	3 418.57	0.50	0.08	27.62	0.001	0.001	0.010
1993	0.60	0.59	0.000004	0.00002	3 498.30	3 461.57	0.45	0.09	27.61	0.001	0.001	0.010
1994	0.70	0.70	0.000005	0.00002	3 559.89	3 521.22	0.43	0.09	26.79	0.001	0.001	0.009
1995	0.76	0.75	0.000005	0.00002	3 384.39	3 347.31	0.37	0.09	21.69	0.001	0.001	0.008
1996	0.77	0.77	0.000006	0.00002	3 484.61	3 446.92	0.35	0.10	24.25	0.001	0.001	0.008
1997	0.79	0.78	0.000006	0.00002	3 688.27	3 649.84	0.33	0.10	23.83	0.001	0.001	0.008
1998	0.68	0.67	0.000005	0.00002	3 857.47	3 819.56	0.31	0.10	23.84	0.001	0.001	0.008
1999	0.69	0.69	0.000005	0.00002	4 163.03	4 124.63	0.29	0.10	23.84	0.001	0.001	0.008
2000	0.66	0.65	0.000005	0.00002	4 812.36	4 772.71	0.27	0.11	23.58	0.001	0.001	0.008
2001	0.65	0.65	0.000005	0.00002	5 026.47	4 988.10	0.25	0.11	25.41	0.001	0.001	0.009
2002	0.61	0.60	0.000004	0.00002	5 172.15	5 135.74	0.22	0.10	22.45	0.001	0.001	0.008
2003	0.71	0.70	0.000005	0.00002	5 610.09	5 574.02	0.21	0.10	19.58	0.001	0.001	0.007
2004	0.62	0.61	0.000004	0.00002	6 567.68	6 531.41	0.20	0.11	15.57	0.001	0.001	0.005
2005	0.61	0.61	0.000004	0.00002	6 966.30	6 931.67	0.17	0.10	9.89	0.000	0.000	0.003
2006	0.52	0.52	0.000004	0.00001	6 666.01	6 633.29	0.14	0.10	7.37	0.000	0.000	0.003
2007	0.55	0.55	0.000004	0.00002	6 396.76	6 362.17	0.13	0.11	10.49	0.001	0.001	0.004
2008	0.53	0.52	0.000004	0.00002	6 521.84	6 483.63	0.11	0.12	12.05	0.001	0.001	0.004
2009	0.54	0.54	0.000004	0.00002	6 027.63	5 989.21	0.10	0.12	11.60	0.001	0.001	0.004
2010	0.53	0.53	0.000004	0.00002	6 357.76	6 314.98	0.09	0.14	12.49	0.001	0.001	0.004
2011	0.57	0.56	0.000004	0.00002	6 774.53	6 725.37	0.09	0.16	12.50	0.001	0.001	0.004
2012	0.49	0.49	0.000004	0.00001	6 500.30	6 450.55	0.08	0.16	11.38	0.001	0.001	0.004
2013	0.47	0.47	0.000003	0.00001	6 360.29	6 310.00	0.07	0.16	9.84	0.000	0.000	0.003
2014	0.50	0.50	0.000004	0.00001	6 083.68	6 032.49	0.09	0.16	11.31	0.001	0.001	0.004
<b>Trend 1990-2014</b>	133.83%	133.83%	133.83%	133.83%	128.78%	129.23%	-81.50%	207.03%	-59.03%	-59.03%	-59.03%	-59.03%

1A3 - Transport								
GHG emissions by source & sink category (Gg)								
Year	1A3d - Navigation				1A3 - Transport			
	Total CO <sub>2</sub> eq	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Total CO <sub>2</sub> eq	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
1990	1.30	1.28	0.0003	0.00004	2 688.26	2 633.15	0.46	0.06
1991	1.49	1.46	0.0004	0.00005	3 191.22	3 130.95	0.51	0.08
1992	1.37	1.34	0.0004	0.00004	3 483.88	3 420.37	0.50	0.09
1993	1.43	1.41	0.0004	0.00004	3 527.93	3 463.57	0.46	0.09
1994	1.34	1.32	0.0004	0.00004	3 588.73	3 523.24	0.43	0.10
1995	1.19	1.17	0.0003	0.00004	3 408.03	3 349.24	0.37	0.10
1996	1.17	1.16	0.0003	0.00004	3 510.81	3 448.84	0.35	0.11
1997	1.22	1.20	0.0003	0.00004	3 714.11	3 651.82	0.34	0.11
1998	1.17	1.15	0.0003	0.00004	3 883.15	3 821.38	0.31	0.11
1999	1.33	1.31	0.0003	0.00004	4 188.88	4 126.63	0.29	0.11
2000	1.15	1.13	0.0003	0.00004	4 837.74	4 774.50	0.27	0.12
2001	1.28	1.26	0.0003	0.00004	5 053.81	4 990.01	0.25	0.12
2002	1.37	1.35	0.0003	0.00004	5 196.59	5 137.70	0.22	0.11
2003	1.49	1.46	0.0003	0.00005	5 631.86	5 576.18	0.21	0.11
2004	1.35	1.33	0.0003	0.00004	6 585.22	6 533.36	0.20	0.11
2005	1.43	1.41	0.0003	0.00005	6 978.24	6 933.69	0.17	0.11
2006	1.35	1.33	0.0002	0.00004	6 675.26	6 635.14	0.15	0.10
2007	1.38	1.36	0.0002	0.00005	6 409.18	6 364.08	0.13	0.11
2008	1.50	1.48	0.0002	0.00005	6 535.92	6 485.64	0.11	0.12
2009	1.28	1.26	0.0002	0.00004	6 041.05	5 991.01	0.10	0.12
2010	1.38	1.36	0.0002	0.00005	6 372.17	6 316.87	0.09	0.14
2011	1.29	1.27	0.0002	0.00004	6 788.89	6 727.20	0.09	0.16
2012	1.31	1.29	0.0002	0.00004	6 513.47	6 452.32	0.08	0.16
2013	1.15	1.13	0.0002	0.00004	6 371.75	6 311.60	0.07	0.17
2014	1.22	1.21	0.0002	0.00004	6 096.72	6 034.19	0.09	0.17
<b>Trend 1990-2014</b>	-5.66%	-5.44%	-41.83%	-5.33%	126.79%	129.16%	-81.41%	166.62%

Notes:

CH<sub>4</sub> emissions are converted in CO<sub>2</sub>e 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<sub>2</sub>O emissions are converted in CO<sub>2</sub>e 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 2014, domestic aviation fuel consumption was responsible for 0.0054% of GHG emissions from fuel combustion activities (0.0021% in 1990) and represented 0.0047% of the national total GHG emissions in CO<sub>2</sub>e, excluding LULUCF (0.0017% in 1990). Compared to 2013, emissions increased by 6.32%, and compared to 1990 they increased by 133.83%. In absolute terms, 1A3a emitted 0.50 Gg CO<sub>2</sub>e in 2014.

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 flights. 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 where more details on the split between domestic aviation and international aviation are described.

### 3.2.8.2.2.3 Emission factors

Default CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O 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 3-54.

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 3-54– Activity data and emission factors for IPCC sub-category 1A3a – Domestic aviation: 1990-2014**

1A3a - Civil Aviation Aviation Gasoline								
Year	Activity (GJ)	Emission Factors (kg/TJ)						source
		CO <sub>2</sub>	type	CH <sub>4</sub>	type	N <sub>2</sub> O	type	
1990	3 069	69 300	D	0.50	D	2.00	D	2006 IPCC GL
1991	4 662	69 300	D	0.50	D	2.00	D	2006 IPCC GL
1992	6 579	69 300	D	0.50	D	2.00	D	2006 IPCC GL
1993	8 514	69 300	D	0.50	D	2.00	D	2006 IPCC GL
1994	10 071	69 300	D	0.50	D	2.00	D	2006 IPCC GL
1995	10 845	69 300	D	0.50	D	2.00	D	2006 IPCC GL
1996	11 078	69 300	D	0.50	D	2.00	D	2006 IPCC GL
1997	11 232	69 300	D	0.50	D	2.00	D	2006 IPCC GL
1998	9 667	69 300	D	0.50	D	2.00	D	2006 IPCC GL
1999	9 887	69 300	D	0.50	D	2.00	D	2006 IPCC GL
2000	9 418	69 300	D	0.50	D	2.00	D	2006 IPCC GL
2001	9 354	69 300	D	0.50	D	2.00	D	2006 IPCC GL
2002	8 670	69 300	D	0.50	D	2.00	D	2006 IPCC GL
2003	10 095	69 300	D	0.50	D	2.00	D	2006 IPCC GL
2004	8 850	69 300	D	0.50	D	2.00	D	2006 IPCC GL
2005	8 768	69 300	D	0.50	D	2.00	D	2006 IPCC GL
2006	7 466	69 300	D	0.50	D	2.00	D	2006 IPCC GL
2007	7 904	69 300	D	0.50	D	2.00	D	2006 IPCC GL
2008	7 576	69 300	D	0.50	D	2.00	D	2006 IPCC GL
2009	7 739	69 300	D	0.50	D	2.00	D	2006 IPCC GL
2010	7 646	69 300	D	0.50	D	2.00	D	2006 IPCC GL
2011	8 120	69 300	D	0.50	D	2.00	D	2006 IPCC GL
2012	7 059	69 300	D	0.50	D	2.00	D	2006 IPCC GL
2013	6 749	69 300	D	0.50	D	2.00	D	2006 IPCC GL
2014	7 176	69 300	D	0.50	D	2.00	D	2006 IPCC GL
<b>Trend 1990-2014</b>	133.83%	NA	NA	NA	NA	NA	NA	NA

Source: Environment Agency

### 3.2.8.3 Road Transportation (1A3b)

#### 3.2.8.3.1 Source category description

In 2014, road transportation was responsible for 64.96% of GHG emissions from fuel combustion activities (this share was only 25.59% in 1990) and represented 56.48% of the national total GHG emissions excluding LULUCF (20.66% in 1990). In absolute terms, GHG emissions from road

transportation reached 6 084 Gg CO<sub>2</sub>e. Compared to 2013, GHG emissions decreased by about 4.35%.

With 56.48% of the total GHG emissions from Luxembourg, road transportation is the largest key category in 2014. With regard to CO<sub>2</sub>, it 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 3-55.

**Table 3-55 – Activity data, emission, and implied emission factor trends of IPCC sub-category 1A3b – Road Transportation: 1990-2014**

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 <sub>2</sub> eq	CO <sub>2</sub> (excl. biomass)	CH <sub>4</sub> (incl. biomass)	N <sub>2</sub> O (incl. biomass)	CO <sub>2</sub> (excl. biomass)	CH <sub>4</sub> (incl. biomass)	N <sub>2</sub> O (incl. biomass)
1990	36 095 312	17 742 786	18 178 185	174 340	NO	2 659.14	2 631.66	0.46	0.05	72 909	13	1
1991	42 904 458	20 798 622	21 923 308	182 528	NO	3 161.80	3 129.17	0.51	0.07	72 933	12	2
1992	46 852 648	22 498 982	24 203 430	150 236	NO	3 454.44	3 418.57	0.50	0.08	72 964	11	2
1993	47 452 313	22 614 604	24 677 354	160 356	NO	3 498.30	3 461.57	0.45	0.09	72 948	10	2
1994	48 288 723	23 455 249	24 674 131	159 344	NO	3 559.89	3 521.22	0.43	0.09	72 920	9	2
1995	45 901 419	22 127 237	23 620 635	153 548	NO	3 384.39	3 347.31	0.37	0.09	72 924	8	2
1996	47 250 091	22 435 446	24 699 415	115 230	NO	3 484.61	3 446.92	0.35	0.10	72 950	7	2
1997	50 013 161	23 333 601	26 626 293	53 268	NO	3 688.27	3 649.84	0.33	0.10	72 978	7	2
1998	52 320 884	23 456 196	28 735 796	128 892	NO	3 857.47	3 819.56	0.31	0.10	73 003	6	2
1999	56 470 970	24 254 613	32 097 033	119 324	NO	4 163.03	4 124.63	0.29	0.10	73 040	5	2
2000	65 277 865	25 044 335	40 141 622	91 908	NO	4 812.36	4 772.71	0.27	0.11	73 114	4	2
2001	68 189 570	24 619 557	43 451 793	118 220	NO	5 026.47	4 988.10	0.25	0.11	73 151	4	2
2002	70 173 978	24 000 125	46 056 599	117 254	NO	5 172.15	5 135.74	0.22	0.10	73 186	3	1
2003	76 104 614	24 425 936	51 584 838	93 840	NO	5 610.09	5 574.02	0.21	0.10	73 242	3	1
2004	89 048 191	23 683 995	65 283 880	80 316	IE	6 567.68	6 531.41	0.20	0.11	73 347	2	1
2005	94 399 608	21 572 029	72 770 308	57 270	IE	6 966.30	6 931.67	0.17	0.10	73 429	2	1
2006	90 310 170	19 387 531	70 858 929	63 710	IE	6 666.01	6 633.29	0.14	0.10	73 450	2	1
2007	88 442 721	18 606 443	69 773 811	62 468	IE	6 396.76	6 362.17	0.13	0.11	71 936	1	1
2008	90 052 546	17 697 263	72 282 281	73 002	IE	6 521.84	6 483.63	0.11	0.12	71 998	1	1
2009	83 227 728	16 300 889	66 864 770	62 069	IE	6 027.63	5 989.21	0.10	0.12	71 962	1	1
2010	87 611 411	15 159 160	72 390 064	62 187	IE	6 357.76	6 314.98	0.09	0.14	72 079	1	2
2011	93 730 050	15 676 031	78 025 302	28 717	IE	6 774.53	6 725.37	0.09	0.16	71 753	1	2
2012	89 769 612	15 088 148	74 603 014	78 450	IE	6 500.30	6 450.55	0.08	0.16	71 857	1	2
2013	88 057 672	13 718 680	74 285 212	53 780	IE	6 360.29	6 310.00	0.07	0.16	71 658	1	2
2014	85 072 281	13 266 858	71 743 394	62 029	IE	6 083.68	6 032.49	0.09	0.16	70 910	1	2
Trend 1990-2014	135.69%	-25.23%	294.67%	-64.42%	NA	128.78%	129.23%	-81.50%	207.03%	-2.74%	-92.15%	30.27%
Trend 2013-2014	-3.39%	-3.29%	-3.42%	15.34%	NA	-4.35%	-4.40%	24.25%	1.00%	-1.04%	28.61%	4.54%

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 fuel sold, although during recent years the quantities sold seem to stabilize.

Figure 3-7 – Fuel sold trends - indexes - for 1A3b – Road Transportation by fuel type: 1990-2014

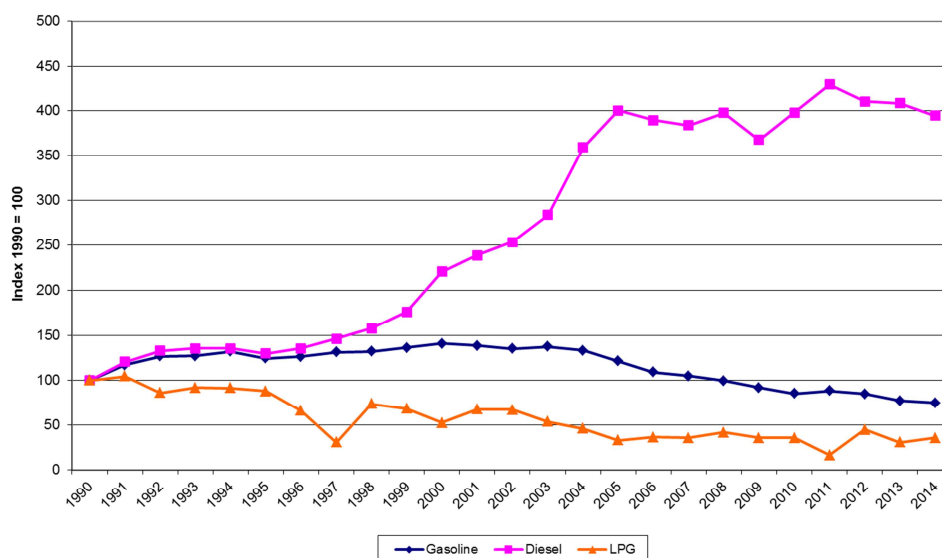


Table 3-56 and Figure 3-8 detail the quantities of blended fuel sold to the domestic fleet and the amount of fuel exported.

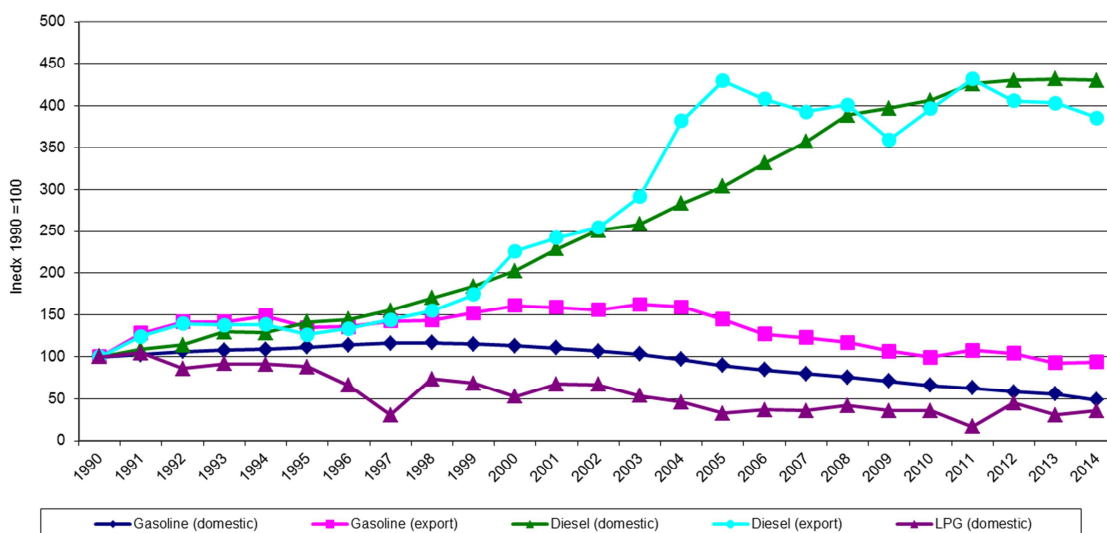
Table 3-56 – Total fuel sold for road transport – inland consumption and road fuel export: 1990-2014

1A3b - Road Transportation											
Blended Fuel sales (t)											
Year	National Total	domestic road fuel sales					road fuel export sales				
		Total	share (%)	Blended Gasoline	Blended Diesel	LPG	Total	share (%)	Blended Gasoline	Blended Diesel	LPG
1990	843 845.0	273 884.0	32.46%	170 818.0	99 275.9	3 790.0	569 961.0	67.54%	241 364.0	328 597.1	NO
1991	1 003 164.7	287 221.2	28.63%	175 196.8	108 056.4	3 968.0	715 943.4	71.37%	307 975.2	407 968.3	NO
1992	1 095 632.5	297 743.0	27.18%	181 261.6	113 215.4	3 266.0	797 889.6	72.82%	341 411.4	456 478.1	NO
1993	1 109 693.6	316 413.8	28.51%	184 458.6	128 469.2	3 486.0	793 279.8	71.49%	340 900.4	452 379.4	NO
1994	1 129 124.8	317 322.9	28.10%	186 260.2	127 598.7	3 464.0	811 801.9	71.90%	358 627.8	453 174.1	NO
1995	1 073 350.9	333 488.0	31.07%	189 864.6	140 285.4	3 338.0	739 862.9	68.93%	324 172.4	415 690.4	NO
1996	1 105 069.9	340 244.7	30.79%	194 585.3	143 154.3	2 505.0	764 825.2	69.21%	326 611.7	438 213.6	NO
1997	1 169 942.2	353 464.3	30.21%	198 282.7	154 023.6	1 158.0	816 477.9	69.79%	343 779.3	472 698.6	NO
1998	1 224 087.1	370 400.5	30.26%	198 907.7	168 690.8	2 802.0	853 686.6	69.74%	346 002.3	507 684.3	NO
1999	1 321 542.9	381 787.1	28.89%	196 689.0	182 504.2	2 594.0	939 755.8	71.11%	366 769.0	572 986.8	NO
2000	1 528 644.2	396 320.3	25.93%	193 301.1	201 021.2	1 998.0	1 132 323.9	74.07%	388 502.9	743 821.0	NO
2001	1 597 262.1	417 870.8	26.16%	188 426.6	226 874.2	2 570.0	1 179 391.3	73.84%	383 509.4	795 881.9	NO
2002	1 644 162.3	433 370.4	26.36%	182 010.7	248 810.6	2 549.0	1 210 791.9	73.64%	375 535.3	835 256.6	NO
2003	1 783 667.4	435 098.9	24.39%	176 231.6	256 827.3	2 040.0	1 348 568.5	75.61%	391 206.4	957 362.1	NO
2004	2 088 615.8	448 620.9	21.48%	165 538.6	281 336.3	1 746.0	1 639 995.0	78.52%	384 663.4	1 255 331.6	NO
2005	2 215 266.7	455 809.2	20.58%	153 142.8	301 421.4	1 245.0	1 759 457.4	79.42%	347 996.2	1 411 461.2	NO
2006	2 119 667.1	474 637.9	22.39%	144 305.3	328 947.6	1 385.0	1 645 029.2	77.61%	306 085.7	1 338 943.4	NO
2007	2 079 541.8	492 558.4	23.69%	136 253.5	354 946.9	1 358.0	1 586 983.4	76.31%	296 749.6	1 290 233.8	NO
2008	2 117 497.8	516 933.5	24.41%	129 704.0	385 642.6	1 587.0	1 600 564.2	75.59%	281 961.3	1 318 602.9	NO
2009	1 957 045.2	517 388.4	26.44%	121 910.8	394 128.3	1 349.3	1 439 656.7	73.56%	257 205.6	1 182 451.1	NO
2010	2 060 570.1	517 505.7	25.11%	112 769.9	403 384.0	1 351.9	1 543 064.3	74.89%	239 811.3	1 303 253.1	NO
2011	2 208 318.7	530 508.0	24.02%	107 490.8	422 393.0	624.3	1 677 810.7	75.98%	260 417.9	1 417 392.7	NO
2012	2 112 159.1	528 172.9	25.01%	99 995.5	426 472.0	1 705.4	1 583 986.2	74.99%	251 265.5	1 332 720.8	NO
2013	2 072 372.4	524 319.9	25.30%	94 950.5	428 200.4	1 169.1	1 548 052.4	74.70%	224 124.1	1 323 928.4	NO
2014	2 004 782.0	511 145.8	25.50%	82 870.2	426 927.1	1 348.5	1 493 636.3	74.50%	227 145.4	1 266 490.8	NO
Trend 1990-2014	137.58%	86.63%	NA	-51.49%	330.04%	-64.42%	162.06%	NA	-5.89%	285.42%	NA
Trend 2013-2014	-3.26%	-2.51%	NA	-12.72%	-0.30%	15.34%	-3.52%	NA	1.35%	-4.34%	NA
Share 1990	NA	32.46%	NA	62.37%	36.25%	1.38%	67.54%	NA	42.35%	57.65%	NA
Share 2014	NA	25.50%	NA	4.13%	21.30%	0.07%	74.50%	NA	11.33%	63.17%	NA

Source: Environment Agency



**Figure 3-8 – Domestic and exported fuel sold trends - indexes - for 1A3b – Road Transportation by fuel type: 1990-2014**



In 2014, as shown in Table 3-57, emissions from road fuel export were nearly three times higher than those from the domestic fleet.

**Table 3-57 – Domestic and road fuel export emissions for 1A3b - Road Transportation: 1990-2014**

1A3b - Road Transportation												
CO <sub>2</sub> eq emissions (Gg)												
Year	National Total (excl. CO <sub>2</sub> from biomass)	CO <sub>2</sub> from biomass	domestic road fuel emissions (excl. CO <sub>2</sub> from biomass)					road fuel export emissions (excl. CO <sub>2</sub> from biomass)				
			Total	share (%)	Gasoline	Diesel	LPG	Total	share (%)	Gasoline	Diesel	LPG
1990	2659.14	NO	863.46	32.47%	539.52	312.39	11.55	1795.67	67.53%	762.09	1033.58	NO
1991	3161.80	NO	905.63	28.64%	553.39	340.15	12.10	2256.17	71.36%	972.50	1283.66	NO
1992	3454.44	NO	939.16	27.19%	572.63	356.58	9.95	2515.28	72.81%	1078.27	1437.01	NO
1993	3498.30	NO	997.86	28.52%	582.82	404.43	10.62	2500.43	71.48%	1076.85	1423.58	NO
1994	3559.89	NO	1000.85	28.11%	588.63	401.67	10.55	2559.03	71.89%	1133.07	1425.96	NO
1995	3384.39	NO	1051.94	31.08%	600.11	441.66	10.17	2332.44	68.92%	1024.36	1308.08	NO
1996	3484.61	NO	1073.45	30.81%	614.93	450.88	7.63	2411.16	69.19%	1031.89	1379.27	NO
1997	3688.27	NO	1115.00	30.23%	626.20	485.27	3.53	2573.27	69.77%	1085.39	1487.88	NO
1998	3857.47	NO	1167.82	30.27%	627.56	531.74	8.53	2689.65	69.73%	1091.31	1598.34	NO
1999	4163.03	NO	1203.37	28.91%	619.90	575.55	7.92	2959.65	71.09%	1155.55	1804.10	NO
2000	4812.36	NO	1248.62	25.95%	608.58	633.97	6.07	3563.74	74.05%	1222.70	2341.03	NO
2001	5026.47	NO	1316.02	26.18%	592.55	715.68	7.79	3710.44	73.82%	1205.57	2504.88	NO
2002	5172.15	NO	1364.43	26.38%	571.67	785.04	7.72	3807.72	73.62%	1179.01	2628.72	NO
2003	5610.09	NO	1369.83	24.42%	552.90	810.75	6.17	4240.26	75.58%	1226.82	3013.44	NO
2004	6567.68	1.56	1412.44	21.51%	518.81	888.36	5.28	5155.23	78.49%	1205.01	3950.22	NO
2005	6966.30	1.62	1435.47	20.61%	479.47	952.24	3.76	5530.84	79.39%	1088.99	4441.85	NO
2006	6666.01	1.53	1494.92	22.43%	451.38	1039.37	4.18	5171.09	77.57%	956.91	4214.18	NO
2007	6396.76	134.40	1519.74	23.76%	423.87	1091.79	4.09	4877.02	76.24%	922.63	3954.38	NO
2008	6521.84	134.27	1596.23	24.48%	403.63	1187.82	4.77	4925.61	75.52%	876.94	4048.67	NO
2009	6027.63	126.87	1596.91	26.49%	379.30	1213.55	4.06	4430.72	73.51%	799.76	3630.96	NO
2010	6357.76	127.03	1599.66	25.16%	350.65	1244.95	4.06	4758.11	74.84%	745.18	4012.93	NO
2011	6774.53	166.99	1628.61	24.04%	326.16	1300.58	1.88	5145.92	75.96%	789.63	4356.28	NO
2012	6500.30	150.03	1627.34	25.03%	309.90	1312.32	5.12	4872.95	74.97%	778.13	4094.83	NO
2013	6360.29	167.12	1611.35	25.33%	294.91	1312.93	3.51	4748.94	74.67%	695.59	4053.35	NO
2014	6083.68	225.35	1552.34	25.52%	254.29	1294.00	4.05	4531.34	74.48%	696.48	3834.86	NO
Trend 1990-2014	128.78%	NA	79.78%	NA	-52.87%	314.22%	-64.95%	152.35%	NA	-8.61%	271.03%	NA
Trend 2013-2014	-4.35%	34.85%	-3.66%	NA	-13.77%	-1.44%	15.42%	-4.58%	NA	0.13%	-5.39%	NA
Share 1990	NA	NA	32.47%	NA	62.48%	36.18%	1.34%	67.53%	NA	42.44%	57.56%	NA
Share 2014	NA	NA	25.52%	NA	4.18%	21.27%	0.07%	74.48%	NA	11.45%	63.04%	NA

Source: Environment Agency

### 3.2.8.3.2 Methodological issues & time series consistency

### 3.2.8.3.2.1 Activity data

Table 3-58 and Table 3-59 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 243.

**Table 3-58 – 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	36 095 312	22 044 048	475 761	13 541 308	34 195
1991	42 904 458	26 040 820	526 871	16 299 461	37 306
1992	46 852 648	28 225 638	558 472	18 027 238	41 300
1993	47 452 313	28 574 406	624 831	18 204 841	48 236
1994	48 288 723	30 704 950	675 785	16 854 942	53 046
1995	45 901 419	29 257 974	723 791	15 866 578	53 077
1996	47 250 091	30 061 643	759 168	16 374 876	54 404
1997	50 013 161	31 075 858	810 082	18 070 332	56 888
1998	52 320 884	32 007 091	867 002	19 386 875	59 916
1999	56 470 970	34 151 106	1 007 777	21 248 573	63 514
2000	65 277 865	36 269 390	1 105 242	27 836 729	66 504
2001	68 189 570	37 118 795	1 154 271	29 848 034	68 469
2002	70 173 978	37 409 159	1 199 470	31 493 758	71 591
2003	76 104 614	38 848 503	1 197 329	35 984 204	74 579
2004	89 048 191	39 688 011	1 247 942	48 034 892	77 346
2005	94 399 608	38 222 993	1 304 387	54 793 104	79 124
2006	90 310 170	36 405 543	1 359 516	52 464 196	80 914
2007	88 442 721	36 864 715	1 455 333	50 040 028	82 645
2008	90 052 546	36 724 233	1 530 077	51 714 272	83 964
2009	83 227 728	35 401 531	1 540 868	46 199 401	85 928
2010	87 611 411	33 985 786	1 584 907	51 953 447	87 271
2011	93 730 050	35 888 186	1 670 865	56 081 246	89 754
2012	89 769 612	35 350 693	1 721 189	52 606 051	91 680
2013	88 057 672	33 236 145	1 758 785	52 967 671	95 071
2014	85 072 281	32 923 744	1 741 338	50 320 065	87 135
<b>Trend 1990-2014</b>	135.69%	49.35%	266.01%	271.60%	154.82%
Source: Environment Agency					

**Table 3-59 – 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	1 A 3 b i	1 A 3 b ii	1 A 3 b iii	1 A 3 b iv
	Total (incl. biomass)	Passenger cars	LDV	HDV and buses	Mopeds & motorcycles
1990	11 745 111	8 651 330	475 761	2 583 825	34 195
1991	12 314 827	8 969 198	526 871	2 781 452	37 306
1992	12 762 778	9 331 819	558 472	2 831 188	41 300
1993	13 558 577	9 685 751	624 831	3 199 759	48 236
1994	13 598 130	9 999 680	675 785	2 869 618	53 046
1995	14 286 484	10 361 333	723 791	3 148 283	53 077
1996	14 573 261	10 810 651	759 168	2 949 039	54 404
1997	15 132 240	11 250 165	810 082	3 015 104	56 888
1998	15 857 903	11 799 473	867 002	3 131 513	59 916
1999	16 339 686	12 277 628	1 007 777	2 990 767	63 514
2000	16 953 133	12 651 604	1 105 242	3 129 782	66 504
2001	17 867 981	13 132 461	1 154 271	3 512 780	68 469
2002	18 522 808	13 424 643	1 199 470	3 827 104	71 591
2003	18 591 215	13 530 774	1 197 329	3 788 533	74 579
2004	19 158 395	13 937 237	1 247 942	3 895 869	77 346
2005	19 455 079	14 165 875	1 304 387	3 905 693	79 124
2006	20 250 533	14 663 691	1 359 516	4 146 413	80 914
2007	20 971 040	15 128 497	1 455 333	4 304 563	82 645
2008	22 005 188	15 860 326	1 530 077	4 530 821	83 964
2009	22 019 365	16 008 878	1 540 868	4 383 691	85 928
2010	22 020 960	15 724 660	1 584 907	4 624 121	87 271
2011	22 522 419	15 897 255	1 670 865	4 864 546	89 754
2012	22 459 302	15 927 095	1 721 189	4 719 338	91 680
2013	22 290 658	15 871 544	1 758 785	4 565 258	95 071
2014	21 695 596	15 064 087	1 741 338	4 803 037	87 135
<b>Trend</b>					
<b>1990-2014</b>	84.72%	74.12%	266.01%	85.89%	154.82%

Source: Environment Agency

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).

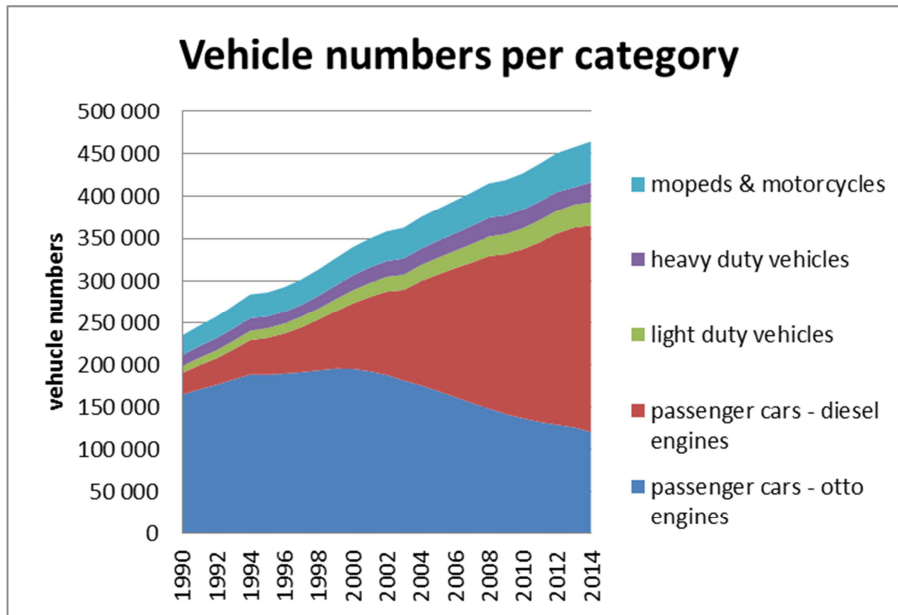


Figure 3-10 – Total mileage in Luxembourg.

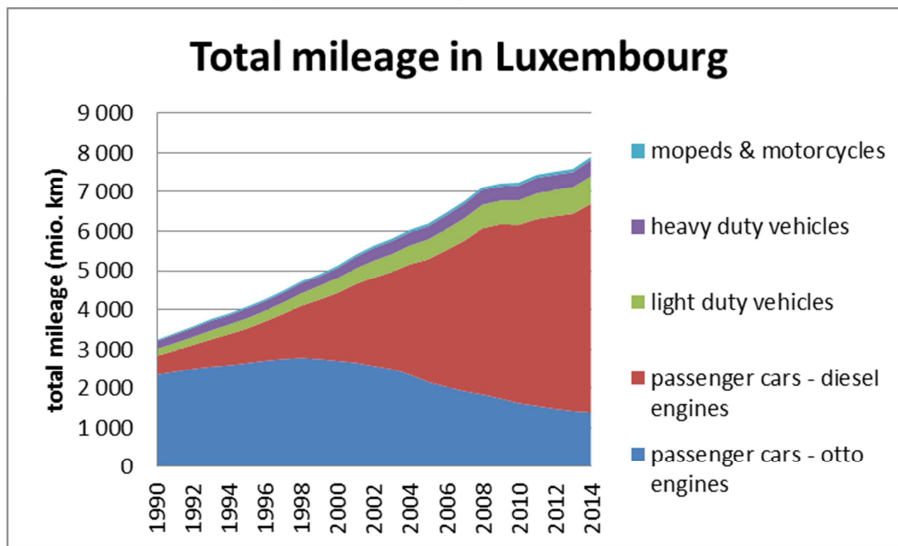
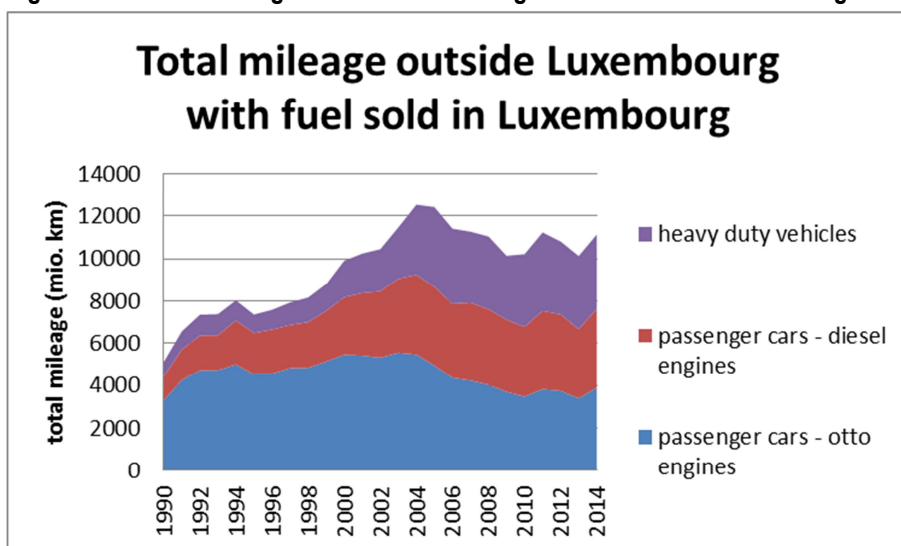


Figure 3-11 shows that the total mileage driven outside Luxembourg with fuel purchased in Luxembourg has approximately doubled since 1990. While the mileage driven with gasoline exported in passenger car tanks has remained relatively stable, the mileage driven with diesel exported from Luxembourg in the tanks of passenger cars and heavy duty vehicles has significantly increased.

Figure 3-11 – Total mileage outside Luxembourg with fuel sold in Luxembourg.



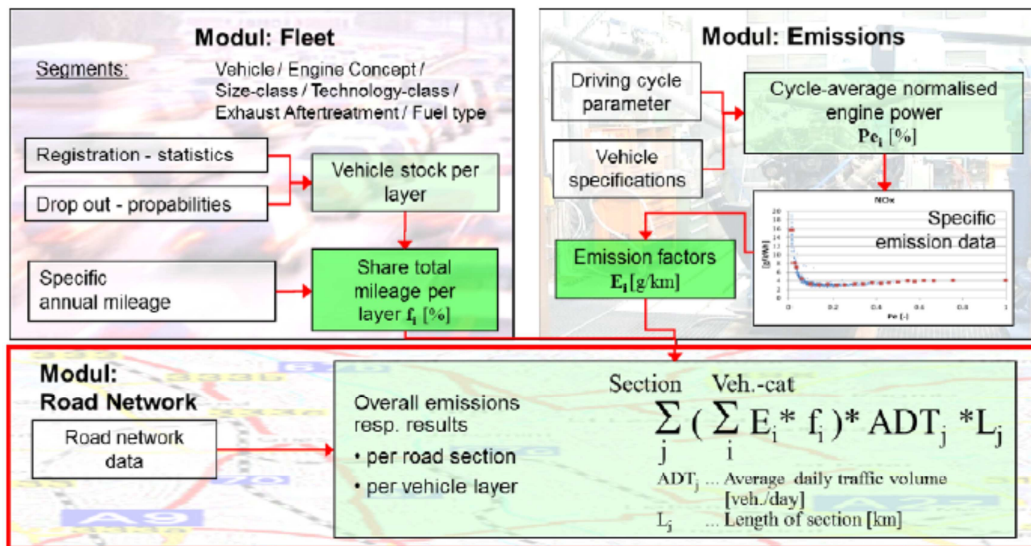
3.2.8.3.2.2 Methodology - The model NEMO and its application to Luxembourg's road transport situation  
The model NEMO (Network Emission Model) was developed at the Institute for Internal Combustion Engines and Thermodynamics (IVT) at the Graz University of Technology (TUG) as tool for the simulation 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<sup>101</sup>. 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 ( $\text{NO}_x$ , 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  $\text{CO}_2$  and  $\text{SO}_2$  are simulated based on fuel consumption and fuel specifications. The non-regulated pollutants  $\text{N}_2\text{O}$ ,  $\text{NH}_3$ ,  $\text{CH}_4$ , NMVOC and  $\text{C}_6\text{H}_6$  are calculated with an approach similar to the HBEFA 3.2 based on fixed emission factors for certain vehicle categories and driving situations.

<sup>101</sup> Handbook emission factors for road transport (HBEFA) <http://www.hbefa.net/>

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<sup>102</sup>
- Calibration of fuel consumption based on statistics of g/km CO<sub>2</sub> of new registered vehicles in the NEDC type approval and literature on the discrepancies between NEDC and real world CO<sub>2</sub> reduction rates<sup>103</sup>
- 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<sup>104</sup>.

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
- (vii) finally the emissions caused by domestic fuel use and exported fuel are calculated separately by NEMO.

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<sup>102</sup> Samaras, Z. (2004). Artemis Subtask 3123: Investigation of the emission degradation of gasoline vehicles, Aristotle University of Thessaloniki - Lab of Applied Thermodynamics

<sup>103</sup> 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<sub>2</sub> values

<sup>104</sup> 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

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 1990-2013<sup>105</sup>. However, no additional study was carried out to include the year 2014, and the emissions from that year were determined as follows:

- For each fuel type, the total national consumption allocated to road transportation in 2014 is based on the national energy balance provided by Statec.
- For 2014, the allocation of fuels to the different vehicle categories as well as the split between fuel used and fuel export was done to reflect the proportions projected by a business-as-usual-scenario.
- 2014 emissions were calculated by using the implied emission factors projected by a business-as-usual-scenario.

It is planned to reconduct a detailed study (such as the one carried out for the timeseries 1990-2013) every few years in order to replace the projected data.

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<sub>2</sub> implied emission factors<sup>106</sup> 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 3-60. The CO<sub>2</sub> IEFs for gasoline and diesel result from dividing fossil CO<sub>2</sub> 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<sub>2</sub> IEFs in this table are slightly lower. The changes of CH<sub>4</sub> and N<sub>2</sub>O IEFs over time are due to new developments in vehicle technology.

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<sup>105</sup> Komobile, FVT: Aktualisierung der Zeitreihen zum Kraftstoffexport und der Emissionen von klimarelevanten Gasen und Luftschadstoffen des Verkehrssektors in Luxemburg von 1990 – 2012, Endbericht, 2014, Graz, Luxemburg

<sup>106</sup> UNFCCC SAI Report 2008, FCCC/WEB/SAI/2008, Table 1.30, p.66



**Table 3-60 – Implied emission factors per fuel type for IPCC sub-category 1A3b – Road Transport: 1990-2014**

1A3b - Road Transportation Implied Emission Factors (kg/TJ)												
Year	Gasoline (blended)			Diesel (blended)			LPG			Biomass		
	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
1990	72 000	24.63	2.50	73 871	1.05	0.50	65 040	20.00	2.41	NA	NA	NA
1991	72 000	23.31	2.62	73 885	1.00	0.54	65 044	18.93	2.53	NA	NA	NA
1992	72 000	21.03	2.85	73 910	0.97	0.58	64 972	17.11	2.77	NA	NA	NA
1993	72 000	18.92	3.08	73 870	0.96	0.62	64 933	15.36	2.99	NA	NA	NA
1994	72 000	17.05	3.28	73 846	0.96	0.69	64 933	13.83	3.19	NA	NA	NA
1995	72 000	15.69	3.43	73 841	0.94	0.72	64 933	12.71	3.34	NA	NA	NA
1996	72 000	14.58	3.48	73 851	0.89	0.76	64 933	11.83	3.40	NA	NA	NA
1997	72 000	13.39	3.42	73 850	0.82	0.79	64 933	10.90	3.36	NA	NA	NA
1998	72 000	12.11	3.28	73 857	0.75	0.84	64 953	9.80	3.21	NA	NA	NA
1999	72 000	10.89	3.12	73 855	0.70	0.89	65 264	8.79	3.05	NA	NA	NA
2000	72 000	9.85	2.94	73 827	0.64	0.90	64 943	7.94	2.88	NA	NA	NA
2001	72 000	8.96	2.73	73 825	0.59	0.92	64 942	7.18	2.66	NA	NA	NA
2002	72 000	8.18	2.48	73 825	0.55	0.93	64 957	6.51	2.43	NA	NA	NA
2003	72 000	7.51	2.26	73 844	0.51	0.91	64 976	5.97	2.22	NA	NA	NA
2004	72 000	6.92	2.05	73 846	0.48	0.85	64 949	5.47	2.01	NA	NA	NA
2005	72 000	6.40	1.84	73 859	0.45	0.84	64 952	5.01	1.80	NA	NA	NA
2006	72 000	5.97	1.64	73 855	0.41	0.91	64 956	4.62	1.61	NA	NA	NA
2007	71 792	5.57	1.46	71 980	0.35	1.10	64 933	4.28	1.43	NA	NA	NA
2008	71 844	5.21	1.30	72 043	0.29	1.31	64 933	3.95	1.26	NA	NA	NA
2009	71 865	4.93	1.15	71 992	0.25	1.51	64 957	3.70	1.13	NA	NA	NA
2010	71 859	4.71	1.04	72 132	0.22	1.65	64 933	3.50	1.02	NA	NA	NA
2011	70 780	4.51	0.96	71 950	0.19	1.82	64 933	3.35	0.94	NA	NA	NA
2012	71 746	4.27	0.87	71 886	0.17	1.97	64 933	3.12	0.85	NA	NA	NA
2013	71 860	4.11	0.80	71 625	0.16	2.04	64 933	2.90	0.77	NA	NA	NA
2014	71 301	5.59	0.75	70 843	0.15	2.16	64 933	4.85	0.76	NA	NA	NA
Trend 1990-2014	-0.97%	-77.32%	-69.79%	-4.10%	-85.92%	332.98%	-0.17%	-75.74%	-68.48%	NA	NA	NA

Source: Environment Agency

Table 3-61, Table 3-62, Table 3-63 and Table 3-64 present the implied emission factors for each vehicle category.

**Table 3-61 – Implied emission factors for passenger cars.**

1 A Mobile Fuel Combustion			
<i>Implied Emission Factor (IEF) of GHG by source category (g/GJ)</i>			
Year	1 A 3 b i Road transport: Passenger cars		
	<i>CO<sub>2</sub> (fossil)</i>	<i>CH<sub>4</sub></i>	<i>N<sub>2</sub>O</i>
1990	72887	19.890	2.070
1991	72841	18.706	2.198
1992	72740	16.810	2.409
1993	72760	14.993	2.604
1994	72779	13.052	2.728
1995	72796	11.859	2.847
1996	72725	10.855	2.884
1997	72580	9.982	2.879
1998	72762	8.826	2.786
1999	72770	7.686	2.669
2000	72735	6.752	2.558
2001	72825	5.892	2.428
2002	72862	5.182	2.293
2003	72846	4.651	2.178
2004	72889	4.061	2.073
2005	72922	3.526	1.982
2006	72995	3.078	1.911
2007	73028	2.712	1.856
2008	73095	2.408	1.810
2009	73117	2.153	1.782
2010	73150	1.974	1.767
2011	73101	1.844	1.761
2012	73205	1.694	1.757
2013	73193	1.556	1.774
2014	73235	2.171	1.777
Source: Environment Agency			

**Table 3-62 – Implied emission factors for light duty vehicles.**

1 A Mobile Fuel Combustion			
<i>Implied Emission Factor (IEF) of GHG by source category (g/GJ)</i>			
Year	1 A 3 b ii Road transport: Light duty vehicles		
	<i>CO<sub>2</sub> (fossil)</i>	<i>CH<sub>4</sub></i>	<i>N<sub>2</sub>O</i>
1990	73308	7.529	0.882
1991	73366	6.607	0.805
1992	73427	5.807	0.741
1993	73453	4.967	0.652
1994	73479	4.343	0.719
1995	73514	3.867	0.879
1996	73558	3.452	1.010
1997	73607	2.938	1.103
1998	73654	2.493	1.201
1999	73690	2.080	1.311
2000	73693	1.754	1.432
2001	73705	1.521	1.556
2002	73719	1.296	1.662
2003	73748	1.107	1.748
2004	73792	0.905	1.815
2005	73815	0.763	1.890
2006	73817	0.656	1.955
2007	73809	0.553	2.001
2008	73828	0.457	2.035
2009	73826	0.388	2.060
2010	73830	0.332	2.078
2011	73826	0.282	2.096
2012	73827	0.241	2.116
2013	73834	0.205	2.135
2014	73849	0.205	2.081
Source: Environment Agency			

**Table 3-63 – Implied emission factors for heavy duty vehicles.**

1 A Mobile Fuel Combustion			
<i>Implied Emission Factor (IEF) of GHG by source category (g/GJ)</i>			
Year	1 A 3 b iii Road transport: Heavy duty vehicles		
	<i>CO<sub>2</sub> (fossil)</i>	<i>CH<sub>4</sub></i>	<i>N<sub>2</sub>O</i>
1990	73871	0.763	0.556
1991	73885	0.752	0.551
1992	73910	0.766	0.554
1993	73870	0.804	0.564
1994	73846	0.838	0.577
1995	73841	0.853	0.583
1996	73851	0.829	0.582
1997	73850	0.779	0.577
1998	73857	0.732	0.575
1999	73855	0.689	0.572
2000	73827	0.648	0.561
2001	73825	0.610	0.535
2002	73825	0.574	0.498
2003	73844	0.540	0.461
2004	73870	0.511	0.429
2005	73882	0.479	0.430
2006	73876	0.438	0.483
2007	73862	0.376	0.676
2008	73874	0.308	0.947
2009	73867	0.260	1.177
2010	73867	0.222	1.401
2011	73859	0.190	1.622
2012	73857	0.165	1.798
2013	73862	0.152	1.891
2014	73874	0.122	2.035
Source: Environment Agency			

**Table 3-64 – 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 <sub>2</sub> (fossil)	CH <sub>4</sub>	N <sub>2</sub> O
1990	72000	216.862	1.251
1991	72000	201.006	1.263
1992	72000	187.503	1.275
1993	72000	163.798	1.293
1994	72000	151.094	1.305
1995	72000	150.825	1.306
1996	72000	148.277	1.308
1997	72000	143.675	1.312
1998	72000	139.051	1.316
1999	72000	133.399	1.321
2000	72000	129.847	1.325
2001	72000	127.855	1.327
2002	72000	124.947	1.329
2003	72000	121.879	1.332
2004	72000	117.320	1.335
2005	72000	113.170	1.337
2006	72000	109.601	1.338
2007	72000	105.965	1.340
2008	72000	103.159	1.340
2009	72000	100.146	1.341
2010	72000	98.124	1.342
2011	72000	95.547	1.343
2012	72000	92.633	1.344
2013	72000	87.495	1.348
2014	72000	81.498	1.342
Source: Environment Agency			

### 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 2014, railways fuel consumption was responsible for 0.12% of GHG emissions from fuel combustion activities (0.27% in 1990) and represented 0.11% of the total GHG emissions in CO<sub>2</sub>e, excluding LULUCF (0.21% in 1990). Compared to 2013, emissions increased by 14.97% to reach 11.31 Gg CO<sub>2</sub>e in 2014. Compared to 1990, emissions decreased by 59.03%.

Activity data, GHG emissions and emission factors used to estimate emissions from 1A3c are shown in Table 3-65. 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 3-65 – Activity data, emissions and emission factors for IPCC sub-category 1A3c – Railways: 1990-2014**

1A3c - Railways												
Diesel Oil												
Year	Activity (GJ)	Emissions (Gg)				Emission Factors (kg/TJ)						
		Total CO <sub>2</sub> eq	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	type	CH <sub>4</sub>	type	N <sub>2</sub> O	type	source
1990	334 678	27.61	24.72	0.0014	0.0096	73 871	CS	4.15	D	28.60	D	AEV, 2006 IPCC GL
1991	334 678	27.61	24.73	0.0014	0.0096	73 885	CS	4.15	D	28.60	D	AEV, 2006 IPCC GL
1992	334 678	27.62	24.74	0.0014	0.0096	73 910	CS	4.15	D	28.60	D	AEV, 2006 IPCC GL
1993	334 678	27.61	24.72	0.0014	0.0096	73 870	CS	4.15	D	28.60	D	AEV, 2006 IPCC GL
1994	324 884	26.79	23.99	0.0013	0.0093	73 846	CS	4.15	D	28.60	D	AEV, 2006 IPCC GL
1995	263 059	21.69	19.42	0.0011	0.0075	73 841	CS	4.15	D	28.60	D	AEV, 2006 IPCC GL
1996	293 972	24.25	21.71	0.0012	0.0084	73 851	CS	4.15	D	28.60	D	AEV, 2006 IPCC GL
1997	288 989	23.83	21.34	0.0012	0.0083	73 850	CS	4.15	D	28.60	D	AEV, 2006 IPCC GL
1998	288 989	23.84	21.34	0.0012	0.0083	73 857	CS	4.15	D	28.60	D	AEV, 2006 IPCC GL
1999	288 989	23.84	21.34	0.0012	0.0083	73 855	CS	4.15	D	28.60	D	AEV, 2006 IPCC GL
2000	285 971	23.58	21.11	0.0012	0.0082	73 827	CS	4.15	D	28.60	D	AEV, 2006 IPCC GL
2001	308 159	25.41	22.75	0.0013	0.0088	73 825	CS	4.15	D	28.60	D	AEV, 2006 IPCC GL
2002	272 319	22.45	20.10	0.0011	0.0078	73 825	CS	4.15	D	28.60	D	AEV, 2006 IPCC GL
2003	237 417	19.58	17.53	0.0010	0.0068	73 844	CS	4.15	D	28.60	D	AEV, 2006 IPCC GL
2004	188 736	15.57	13.94	0.0008	0.0054	73 870	CS	4.15	D	28.60	D	AEV, 2006 IPCC GL
2005	119 838	9.89	8.85	0.0005	0.0034	73 882	CS	4.15	D	28.60	D	AEV, 2006 IPCC GL
2006	89 359	7.37	6.60	0.0004	0.0026	73 876	CS	4.15	D	28.60	D	AEV, 2006 IPCC GL
2007	127 161	10.49	9.39	0.0005	0.0036	73 862	CS	4.15	D	28.60	D	AEV, 2006 IPCC GL
2008	146 043	12.05	10.79	0.0006	0.0042	73 874	CS	4.15	D	28.60	D	AEV, 2006 IPCC GL
2009	140 637	11.60	10.39	0.0006	0.0040	73 867	CS	4.15	D	28.60	D	AEV, 2006 IPCC GL
2010	151 387	12.49	11.18	0.0006	0.0043	73 867	CS	4.15	D	28.60	D	AEV, 2006 IPCC GL
2011	151 568	12.50	11.19	0.0006	0.0043	73 859	CS	4.15	D	28.60	D	AEV, 2006 IPCC GL
2012	137 941	11.38	10.19	0.0006	0.0039	73 857	CS	4.15	D	28.60	D	AEV, 2006 IPCC GL
2013	119 277	9.84	8.81	0.0005	0.0034	73 862	CS	4.15	D	28.60	D	AEV, 2006 IPCC GL
2014	137 133	11.31	10.13	0.0006	0.0039	73 862	CS	4.15	D	28.60	D	AEV, 2006 IPCC GL
Trend 1990-2014	-59.03%	-59.03%	-59.03%	-59.03%	-59.03%	-0.01%	NA	0.00%	NA	0.00%	NA	NA

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 (2000-2014). 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 1 approach has been applied for CH<sub>4</sub> and N<sub>2</sub>O, whereas the Tier 2 approach has been applied for CO<sub>2</sub> (use of country specific CO<sub>2</sub> emission factor).

##### 3.2.8.4.2.3 Emission factors

The country specific CO<sub>2</sub> EF for diesel oil was used. 2006 IPCC default EFs have been applied for CH<sub>4</sub> and N<sub>2</sub>O (Table 3-65).

### 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 2014, 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<sub>2</sub>e, excluding LULUCF (0.01% in 1990). Compared to 2013, emissions have increased by 6.90%. Compared to 1990, emissions have decreased by 5.66%.

Activity data and GHG emissions from 1A3d are shown in Table 3-66.

Navigation related GHG emissions are not a key source.

**Table 3-66 – Activity data and emissions for IPCC Sub-category 1A3d – Domestic Navigation: 1990-2014**

1A3d - Navigation					
Gas Oil, Diesel Oil, Motor Gasoline					
Year	Activity (GJ)	Emissions (Gg)			
		Total CO <sub>2</sub> eq	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
1990	17 400	1.30	1.28	0.0003	0.00004
1991	19 919	1.49	1.46	0.0004	0.00005
1992	18 317	1.37	1.34	0.0004	0.00004
1993	19 214	1.43	1.41	0.0004	0.00004
1994	18 021	1.34	1.32	0.0004	0.00004
1995	15 950	1.19	1.17	0.0003	0.00004
1996	15 750	1.17	1.16	0.0003	0.00004
1997	16 344	1.22	1.20	0.0003	0.00004
1998	15 630	1.17	1.15	0.0003	0.00004
1999	17 836	1.33	1.31	0.0003	0.00004
2000	15 405	1.15	1.13	0.0003	0.00004
2001	17 150	1.28	1.26	0.0003	0.00004
2002	18 430	1.37	1.35	0.0003	0.00004
2003	19 915	1.49	1.46	0.0003	0.00005
2004	18 105	1.35	1.33	0.0003	0.00004
2005	19 218	1.43	1.41	0.0003	0.00005
2006	18 069	1.35	1.33	0.0002	0.00004
2007	18 449	1.38	1.36	0.0002	0.00005
2008	20 055	1.50	1.48	0.0002	0.00005
2009	17 147	1.28	1.26	0.0002	0.00004
2010	18 531	1.38	1.36	0.0002	0.00005
2011	17 221	1.29	1.27	0.0002	0.00004
2012	17 495	1.31	1.29	0.0002	0.00004
2013	15 342	1.15	1.13	0.0002	0.00004
2014	16 400	1.22	1.21	0.0002	0.00004
<b>Trend 1990-2014</b>	-5.75%	-5.66%	-5.44%	-41.83%	-5.33%

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 3-66.

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.<sup>107</sup> 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 2006 IPCC Guidelines Tier 1 approach has been applied for CH<sub>4</sub> and N<sub>2</sub>O, whereas the Tier 2 approach has been applied for CO<sub>2</sub> (use of country specific CO<sub>2</sub> emission factors).

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 (Merttert), 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<sub>2</sub> EFs for gas oil, diesel oil and gasoline were used. 2006 IPCC default EFs for gas oil have been applied for CH<sub>4</sub> and N<sub>2</sub>O, whereas, for diesel oil and gasoline combusted in the small boats, default EFs from the EMEP/EEA Guidebook 2009 were used.

**Table 3-67 – Emission factors for IPCC sub-category 1A3d – Domestic Navigation**

1A3d - Navigation						
Emission Factors for 2014 (kg/TJ)						
Fuel	Fuel Type	CO <sub>2</sub>		CH <sub>4</sub>		N <sub>2</sub> O
		EF	type	EF	type	EF
Gas Oil	liquid	73 874	CS	7.00	D	2.00
Diesel Oil	liquid	73 874	CS	2.75	D	2.99
Motor Gasoline	liquid	72 000	CS	63.00	D	1.63
						Source
						AEV 2006 IPCC GL
						AEV EMEP/EEA 2009
						AEV EMEP/EEA 2009

<sup>107</sup> ARR 2009, §55



### 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: Other mobile equipment

Pipeline compressors, reported under 1A3e – *Other Transportation*, do not exist in Luxembourg.

### 3.2.8.7 Uncertainties and time-series consistency

For uncertainties on activity data and emission factors, please refer to section 1.7.

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 3-68 presents the main revisions and recalculations done since submission 2015v1.1 relevant to IPCC sub-category 1A3 – *Transport*. For the quantitative aspect of these recalculations, please refer to Chapter 10.

**Table 3-68 – Recalculations done since submission 2015v1.1**

GHG source & sink category	Revisions 2015v1.1 → 2016v1	Type of revision
1A3a	Activity data were revised for 2011 and 2013 as provided by Statec.	updated AD

GHG source & sink category	Revisions 2015v1.1 → 2016v1	Type of revision
1A3b	Activity data were revised due to changes in the fuel consumption allocated to road transportation in the national energy balance provided by Statec. The resulting changes in total GHG emissions from 1A3b are in the range of 1-2%.	updated AD
1A3d	Updated gasoil AD for 2013 as provided by one of the two national operators. Updated diesel oil and gasoline AD for 2013 as provided by the operator of the marina in Schwebsange.	updated AD

### 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 3-69 will be explored.

**Table 3-69 – Planned improvements for IPCC Sub-category 1A3 – Transport**

GHG source & sink category	Planned improvement
1A3b – Road Transportation	It is planned to reconduct a detailed study (such as the one carried out for the timeseries 1990-2013) every few years in order to replace the projected data.

## 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 2014, category *1A4 - Other sectors* was responsible for 15.55% of GHG emissions from fuel combustion activities (this share was 12.82% in 1990) and represented around 13.52% of the total GHG emissions excluding LULUCF (10.35% in 1990).

Compared to 2013, emissions decreased by 10.28%, to attain the level of 1 455.79 Gg CO<sub>2</sub>e. Compared to 1990 emissions increased by 9.31, mainly due to the steady increase in population and economic activity over the last two decades years.

*1A4 – Other Sectors* is a key category with regard to CO<sub>2</sub> 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 3-70 – GHG emission trends for category 1A4 – Other Sectors: 1990-2014

1A4 - Other Sectors												
GHG emissions by source & sink category excluding CO <sub>2</sub> emissions from biomass (Gg)												
Year	1A4a - Commercial/Institutional				1A4b - Residential				1A4c - Agriculture/Forestry/Fisheries			
	Total CO <sub>2</sub> eq	CO <sub>2</sub> (excl. biomass)	CH <sub>4</sub> (incl. biomass)	N <sub>2</sub> O (incl. biomass)	Total CO <sub>2</sub> eq	CO <sub>2</sub> (excl. biomass)	CH <sub>4</sub> (incl. biomass)	N <sub>2</sub> O (incl. biomass)	Total CO <sub>2</sub> eq	CO <sub>2</sub> (excl. biomass)	CH <sub>4</sub> (incl. biomass)	N <sub>2</sub> O (incl. biomass)
1990	640.15	637.04	0.08	0.004	674.09	663.24	0.35	0.007	17.57	16.61	0.002	0.003
1991	770.13	766.34	0.09	0.005	881.04	869.15	0.38	0.008	21.06	19.92	0.002	0.004
1992	710.59	707.15	0.09	0.004	815.14	804.08	0.35	0.007	21.03	19.88	0.002	0.004
1993	702.46	699.10	0.08	0.004	809.19	798.06	0.36	0.007	17.53	16.57	0.002	0.003
1994	676.83	673.60	0.08	0.004	773.57	763.31	0.33	0.007	21.03	19.87	0.002	0.004
1995	682.30	679.09	0.08	0.004	783.54	773.03	0.34	0.007	17.55	16.56	0.002	0.003
1996	761.54	757.98	0.09	0.004	853.46	843.23	0.32	0.007	21.03	19.83	0.002	0.004
1997	738.29	734.79	0.09	0.004	829.15	819.06	0.32	0.007	24.62	23.19	0.002	0.005
1998	772.47	768.82	0.09	0.005	865.99	855.89	0.32	0.007	24.69	23.25	0.002	0.005
1999	692.30	689.09	0.08	0.004	781.95	772.41	0.30	0.007	32.09	31.56	0.004	0.001
2000	599.09	596.87	0.06	0.002	1 146.84	1 135.80	0.34	0.009	50.41	45.21	0.002	0.017
2001	548.91	546.69	0.06	0.002	1 241.58	1 229.84	0.36	0.010	57.59	51.67	0.002	0.020
2002	542.92	540.77	0.06	0.002	1 179.46	1 168.57	0.33	0.009	57.26	51.50	0.002	0.019
2003	544.29	542.20	0.06	0.002	1 224.17	1 213.09	0.34	0.009	62.25	56.28	0.003	0.020
2004	522.42	520.40	0.06	0.002	1 309.70	1 297.94	0.36	0.010	61.75	56.27	0.003	0.018
2005	479.35	477.50	0.05	0.002	1 281.05	1 269.69	0.34	0.009	64.38	59.15	0.003	0.017
2006	468.20	466.60	0.05	0.001	1 269.29	1 257.90	0.34	0.009	67.15	62.05	0.003	0.017
2007	426.34	424.87	0.04	0.001	1 221.69	1 211.16	0.32	0.009	69.08	64.00	0.003	0.017
2008	435.38	433.96	0.04	0.001	1 261.24	1 250.11	0.34	0.009	71.39	66.47	0.003	0.016
2009	438.17	436.76	0.04	0.001	1 255.78	1 244.10	0.36	0.009	80.99	75.73	0.004	0.017
2010	542.41	540.47	0.05	0.002	1 237.17	1 225.60	0.36	0.009	79.34	74.28	0.004	0.017
2011	366.45	365.11	0.04	0.001	1 122.18	1 112.49	0.30	0.008	63.89	60.09	0.003	0.013
2012	473.61	471.94	0.05	0.002	1 157.19	1 146.03	0.34	0.009	65.58	61.85	0.003	0.012
2013	495.33	493.51	0.05	0.002	1 170.10	1 157.50	0.40	0.009	69.11	65.19	0.003	0.013
2014	397.59	396.10	0.04	0.002	1 102.41	1 090.33	0.38	0.008	65.47	61.62	0.003	0.013
Trend 1990-2014	-37.89%	-37.82%	-46.71%	-61.16%	63.54%	64.40%	9.53%	18.81%	272.58%	270.94%	104.72%	309.38%
Trend 2013-2014	-19.73%	-19.74%	-19.25%	-17.84%	-5.78%	-5.80%	-3.04%	-8.33%	-5.26%	-5.46%	-8.17%	-1.77%

Source: Environment Agency

## Notes:

CO<sub>2</sub> emissions do not include CO<sub>2</sub> emissions from biomass which are reported under Memo Items.CH<sub>4</sub> emissions are converted in CO<sub>2</sub>e 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<sub>2</sub>O emissions are converted in CO<sub>2</sub>e 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 2014, fuel combustion activities from the commercial and institutional sector were responsible for 4.22% of GHG emissions from fuel combustion activities (this share was also 6.16% in 1990). With regard to total GHG emissions excluding LULUCF, *1A4a – Commercial/Institutional* covered 3.67% in 2014 and 4.97% in 1990. Compared to 2013, GHG emissions have decreased by 19.84% to reach the level of 395.24 Gg CO<sub>2</sub>e in 2014. 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 38.26%.

#### 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*.

During the last years (Table 3-71), a remarkable shift from liquid fuels towards gaseous fuels has occurred, although the total activity rate of category *1A4a* has been relatively constant until a sharp decrease occurred in 2014, probably due to a relatively mild winter.

**Table 3-71 – 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	9 797 995	NO	2 673 823	7 107 137	17 036	NO
2001	8 702 065	NO	3 312 877	5 364 951	24 238	NO
2002	8 667 675	NO	3 009 270	5 635 253	23 152	NO
2003	8 770 783	NO	2 693 297	6 049 281	28 205	NO
2004	8 376 931	NO	2 685 214	5 665 740	25 976	NO
2005	7 658 985	NO	2 495 701	5 138 049	25 235	NO
2006	7 752 728	NO	1 498 922	6 226 864	26 942	NO
2007	7 070 310	NO	1 383 477	5 660 647	26 187	NO
2008	7 334 296	NO	1 084 008	6 220 542	29 747	NO
2009	7 353 267	NO	1 065 826	6 253 289	34 152	NO
2010	8 862 989	NO	2 378 209	6 453 735	31 045	NO
2011	5 900 003	NO	1 897 457	3 965 598	36 947	NO
2012	7 737 482	NO	2 117 970	5 583 839	35 673	NO
2013	7 996 304	NO	2 553 555	5 400 736	42 014	NO
2014	6 390 611	NO	2 116 444	4 231 100	43 067	NO
<b>Trend 1990-2014</b>	-31.26%	NA	-66.72%	44.08%	NA	NA
<b>Trend 2013-2014</b>	-20.08%	NA	-17.12%	-21.66%	2.51%	NA

Source: Environment Agency

#### 3.2.9.2.2.2 Methodology

The 2006 IPCC Guidelines Tier 2 approach has been applied for CO<sub>2</sub> 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<sub>4</sub> and N<sub>2</sub>O.

#### 3.2.9.2.2.3 Emission factors

Default CH<sub>4</sub> and N<sub>2</sub>O emission factors have been applied for all fuels. For biomass (only biogas is used) the IPCC default CO<sub>2</sub> EF was applied. For gas oil, diesel oil, LPG and natural gas, country specific CO<sub>2</sub> emission factors were used (Table 3-72).

**Table 3-72 – Emission factors for category 1A4a – Commercial/Institutional**

1A4a - Commercial/Institutional Emission Factors for 2014 (kg/TJ)								
Fuel	Fuel Type	CO <sub>2</sub>		CH <sub>4</sub>		N <sub>2</sub> O		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	73 874	CS	10.00	D	0.60	D	AEV 2006 IPCC GL
Natural Gas	gaseous	56 756	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 3-73 gives an overview of the evolution of the implied emission factors per fuel type. The slight fluctuations for the CH<sub>4</sub> and NO<sub>2</sub> IEFs for liquid fuels are due to fluctuations in the fuel mix (gasoil and LPG).

**Table 3-73 – Implied emission factors for IPCC sub-category 1A4a – Commercial/Institutional**

1A4a - Commercial/Institutional Implied Emission Factors (kg/TJ)									
Year	Biomass			Liquid			Gaseous		
	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
1990	NO	NO	NO	73 502	9.79	0.58	57 755	5.00	0.10
1991	NO	NO	NO	73 606	9.84	0.58	57 743	5.00	0.10
1992	NO	NO	NO	73 587	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	54 600	5.00	0.10	73 442	9.78	0.58	56 221	5.00	0.10
2001	54 600	5.00	0.10	73 515	9.83	0.58	56 258	5.00	0.10
2002	54 600	5.00	0.10	73 673	9.91	0.59	56 396	5.00	0.10
2003	54 600	5.00	0.10	73 765	9.96	0.60	56 533	5.00	0.10
2004	54 600	5.00	0.10	73 699	9.90	0.59	56 671	5.00	0.10
2005	54 600	5.00	0.10	73 615	9.85	0.59	56 910	5.00	0.10
2006	54 600	5.00	0.10	73 485	9.78	0.58	57 008	5.00	0.10
2007	54 600	5.00	0.10	73 695	9.91	0.59	56 793	5.00	0.10
2008	54 600	5.00	0.10	73 659	9.88	0.59	56 665	5.00	0.10
2009	54 600	5.00	0.10	73 286	9.67	0.57	57 056	5.00	0.10
2010	54 600	5.00	0.10	72 649	9.32	0.53	56 712	5.00	0.10
2011	54 600	5.00	0.10	72 256	9.10	0.51	56 988	5.00	0.10
2012	54 600	5.00	0.10	72 177	9.06	0.51	56 793	5.00	0.10
2013	54 600	5.00	0.10	72 486	9.23	0.52	56 680	5.00	0.10
2014	54 600	5.00	0.10	72 581	9.28	0.53	56 756	5.00	0.10

Source: Environment Agency

### 3.2.9.3 Residential (1A4b)

#### 3.2.9.3.1 Source category description

In 2014, fuel combustion activities in the residential sector were responsible for 10.70% of GHG emissions from fuel combustion activities (6.49% in 1990). With regard to total GHG emissions excluding LULUCF emissions from 1A4b – Residential reached 9.30% in 2014 and 5.24% in 1990. Compared to 2013, GHG emissions decreased by 6.35%, probably due to a milder 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 2000-2014, 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 obtained from the national statistics institute and is only reported for the years 1998-2000.

Activity data for both stationary and mobile sources, as described above, are listed in Table 3-74.

**Table 3-74 – 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	9 564 974	268 741	6 359 553	2 936 681	645 000	NO
1991	12 080 805	313 244	7 822 330	3 300 231	645 000	NO
1992	11 221 977	253 192	6 985 232	3 338 553	645 000	NO
1993	11 175 946	271 499	6 708 868	3 550 579	645 000	NO
1994	10 722 365	179 141	6 406 937	3 491 287	645 000	NO
1995	10 901 600	214 226	6 223 973	3 818 401	645 000	NO
1996	12 056 736	133 647	6 794 806	4 483 283	645 000	NO
1997	11 675 576	123 577	6 718 170	4 188 829	645 000	NO
1998	12 282 080	89 753	7 040 511	4 506 815	645 000	NO
1999	11 156 121	83 642	5 985 839	4 441 640	645 000	NO
2000	16 616 803	63 651	9 360 253	6 560 642	632 256	NO
2001	18 026 431	51 351	10 051 202	7 241 170	682 708	NO
2002	17 224 203	40 632	9 232 409	7 320 304	630 859	NO
2003	17 929 987	29 511	9 399 832	7 856 398	644 245	NO
2004	19 196 454	27 390	9 966 251	8 516 240	686 572	NO
2005	18 806 933	30 074	9 582 913	8 536 993	656 953	NO
2006	18 490 496	25 786	9 906 170	7 899 632	658 908	NO
2007	17 906 737	21 523	9 436 033	7 861 031	588 151	NO
2008	18 544 383	19 861	9 471 361	8 407 485	645 676	NO
2009	18 346 377	21 702	9 381 386	8 226 956	716 333	NO
2010	18 442 389	25 322	8 072 239	9 602 707	742 120	NO
2011	16 822 075	22 774	7 192 446	9 027 820	579 036	NO
2012	17 059 500	18 751	8 000 314	8 315 615	724 820	NO
2013	17 247 172	26 584	7 525 396	8 797 046	898 147	NO
2014	16 457 056	20 182	6 188 147	9 348 916	899 811	NO
<b>Trend 1990-2014</b>	72.06%	-92.49%	-2.70%	218.35%	39.51%	NA
<b>Trend 2013-2014</b>	-4.58%	-24.08%	-17.77%	6.27%	0.19%	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<sub>2</sub>, while the Tier 1 approach was used for CH<sub>4</sub> and N<sub>2</sub>O.

For mobile sources, the 2006 IPCC Guidelines Tier 2 approach has been applied for CO<sub>2</sub>, while the method used for CH<sub>4</sub> and N<sub>2</sub>O conforms to the requirements of the IPCC 2006 GL Tier 3 methodology. The applied methodology is described in the subchapter on mobile sources of 1.A.2.g.vii – Off-road vehicles and other machinery.

### 3.2.9.3.2.3 Emission factors

Default CH<sub>4</sub> and N<sub>2</sub>O emission factors have been applied, while country specific CO<sub>2</sub> emission factors were used for the main fuels: see Table 3-75.



**Table 3-75 – Emission factors for IPCC sub-category 1A4b – Residential**

1A4b - Residential								
Emission Factors for 2014 (kg/TJ)								
Fuel	Fuel Type	CO <sub>2</sub>		CH <sub>4</sub>		N <sub>2</sub> O		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	73 874	CS	10.00	D	0.60	D	AEV 2006 IPCC GL
Gasoline	liquid	72 000	CS	26.77	CS	1.17	CS	AEV
Natural Gas	gaseous	56 756	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 3-76 gives an overview of the evolution of the implied emission factors per fuel type.

**Table 3-76 – Implied emission factors for IPCC sub-category 1A4b – Residential**

1A4b - Residential									
Implied Emission Factors (kg/TJ)									
Year	Solid			Liquid			Gaseous		
	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
1990	97 464	300.00	1.50	73 502	9.79	0.58	57 755	5.00	0.10
1991	97 593	300.00	1.50	73 606	9.84	0.58	57 743	5.00	0.10
1992	97 515	300.00	1.50	73 587	9.82	0.58	57 848	5.00	0.10
1993	98 441	300.00	1.50	73 565	9.83	0.58	57 894	5.00	0.10
1994	97 530	300.00	1.50	73 563	9.84	0.58	57 940	5.00	0.10
1995	101 287	300.00	1.50	73 570	9.85	0.58	57 929	5.00	0.10
1996	97 350	300.00	1.50	73 584	9.85	0.59	57 546	5.00	0.10
1997	97 367	300.00	1.50	73 706	9.92	0.59	57 205	5.00	0.10
1998	97 365	300.00	1.50	73 665	10.38	0.60	56 863	5.00	0.10
1999	97 303	300.00	1.50	73 671	10.17	0.59	56 522	5.00	0.10
2000	97 500	300.00	1.50	73 709	10.10	0.60	56 221	5.00	0.10
2001	97 500	300.00	1.50	73 722	9.94	0.59	56 258	5.00	0.10
2002	97 500	300.00	1.50	73 775	9.97	0.60	56 396	5.00	0.10
2003	97 500	300.00	1.50	73 822	9.99	0.60	56 533	5.00	0.10
2004	97 500	300.00	1.50	73 824	9.97	0.60	56 671	5.00	0.10
2005	97 500	300.00	1.50	73 812	9.96	0.60	56 910	5.00	0.10
2006	97 500	300.00	1.50	73 817	9.97	0.60	57 008	5.00	0.10
2007	97 500	300.00	1.50	73 837	9.99	0.60	56 793	5.00	0.10
2008	97 500	300.00	1.50	73 849	9.99	0.60	56 665	5.00	0.10
2009	97 500	300.00	1.50	73 801	9.96	0.60	57 056	5.00	0.10
2010	97 500	300.00	1.50	73 762	9.94	0.59	56 712	5.00	0.10
2011	97 500	300.00	1.50	73 819	9.98	0.60	56 988	5.00	0.10
2012	97 500	300.00	1.50	73 842	9.99	0.60	56 793	5.00	0.10
2013	97 500	300.00	1.50	73 842	9.99	0.60	56 680	5.00	0.10
2014	97 500	300.00	1.50	73 848	9.99	0.60	56 756	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 2014, fuel combustion activities in agriculture, as well as in forestry, were responsible for 0.63% of GHG emissions from fuel combustion activities (0.17% in 1990). With regard to total GHG emissions excluding LULUCF, emissions from *1A4c – Agriculture/Forestry/ Fishing/Fish farms* reached 0.55% in 2014 and 0.14% in 1990. Compared to 2013, GHG emissions decreased by 1.75%.

Emissions of *1A4c – Agriculture/Forestry/Fishing* are shown in Table 3-70 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 (900 to 1800 GJ per year). Other fuels might be included elsewhere by the national energy balance.
- *Tractors and harvesters used in agriculture*: Diesel oil consumption, as reported by the national energy balance, was attributed to mobile machinery in agriculture, i.e. tractors, harvesters, etc.

Activity data from both stationary and mobile sources, as described above, are listed in Table 3-77.

**Table 3-77 – 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 <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
1990	224 895	73 871	6.90	13.72	NO	NO	NO	NO	NO	NO
1991	269 553	73 885	6.90	13.73	NO	NO	NO	NO	NO	NO
1992	269 023	73 910	6.89	13.75	NO	NO	NO	NO	NO	NO
1993	224 270	73 870	6.88	13.76	NO	NO	NO	NO	NO	NO
1994	269 089	73 846	6.84	13.93	NO	NO	NO	NO	NO	NO
1995	224 267	73 841	6.79	14.20	NO	NO	NO	NO	NO	NO
1996	268 446	73 851	6.74	14.45	NO	NO	NO	NO	NO	NO
1997	314 039	73 850	6.70	14.70	NO	NO	NO	NO	NO	NO
1998	314 999	73 857	6.66	14.91	NO	NO	NO	54 600	5.00	0.10
1999	428 126	73 855	9.36	3.36	NO	NO	NO	54 600	5.00	0.10
2000	614 855	73 827	3.52	28.49	56 221	5.00	0.10	54 600	5.00	0.10
2001	705 741	73 825	3.47	28.73	56 258	5.00	0.10	54 600	5.00	0.10
2002	704 909	73 825	3.40	28.30	56 396	5.00	0.10	54 600	5.00	0.10
2003	777 116	73 844	3.28	27.55	56 533	5.00	0.10	54 600	5.00	0.10
2004	785 167	73 845	3.11	26.11	56 671	5.00	0.10	54 600	5.00	0.10
2005	834 250	73 858	2.92	24.49	56 910	5.00	0.10	54 600	5.00	0.10
2006	881 025	73 853	2.78	23.26	57 008	5.00	0.10	54 600	5.00	0.10
2007	934 340	71 800	2.76	22.23	56 793	5.00	0.10	54 600	5.00	0.10
2008	976 864	71 872	2.80	21.31	56 665	5.00	0.10	54 600	5.00	0.10
2009	1 118 080	71 811	2.88	20.29	57 056	5.00	0.10	54 600	5.00	0.10
2010	1 082 600	71 966	2.96	19.06	56 712	5.00	0.10	54 600	5.00	0.10
2011	882 095	71 777	3.02	17.97	NO	NO	NO	54 600	5.00	0.10
2012	907 680	71 699	3.13	17.03	NO	NO	NO	54 600	5.00	0.10
2013	952 260	71 408	3.34	16.37	NO	NO	NO	54 600	5.00	0.10
2014	891 225	71 408	3.34	16.37	NO	NO	NO	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<sub>2</sub>, while the Tier 1 approach was used for CH<sub>4</sub> and N<sub>2</sub>O.

For mobile sources, the 2006 IPCC Guidelines Tier 2 approach has been applied for CO<sub>2</sub>, while the method used for CH<sub>4</sub> and N<sub>2</sub>O conforms to the requirements of the IPCC 2006 Guidelines Tier 3 methodology. The applied methodology is described in the subchapter on mobile sources of 1.A.2.g.vii – *Off-road vehicles and other machinery*.

#### 3.2.9.4.2.3 Emission factors

Country-specific CO<sub>2</sub> 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<sub>4</sub>, N<sub>2</sub>O and CO<sub>2</sub> from biomass. For mobile sources, country specific emission factors for CH<sub>4</sub> and N<sub>2</sub>O were used (Table 3-78).

**Table 3-78 – Emission factors for category 1A4c – Agriculture/Forestry/Fishing**

1A4c - Agriculture/Forestry/Fishing Emission Factors for 2014 (kg/TJ)								
Fuel	Fuel Type	CO <sub>2</sub>		CH <sub>4</sub>		N <sub>2</sub> O		Source
		EF	type	EF	type	EF	type	
Gas Oil	liquid	73 874	CS	10.00	D	0.60	D	AEV 2006 IPCC GL
Diesel Oil	liquid	73 874	CS	3.34	CS	16.37	CS	AEV
Biogas	biomass	54 600	D	5.00	D	0.10	D	2006 IPCC GL
Natural Gas	gaseous	56 756	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 3-77.

### 3.2.9.5 Uncertainties and time-series consistency

For uncertainties on activity data and emission factors, please refer to section 1.7.

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 3-79 presents the main revisions and recalculations relevant to category 1A4 – *Other Sectors* since the last submission to the UNFCCC.

**Table 3-79 – Recalculations done since submission 2015v1**

GHG source & sink category	Revisions 2015v1 → 2016v1	Type of revision
1A4	AD for gasoil, natural gas and biomass was revised due to a revised energy balance by the national statistics institute.	updated AD
1A4b, 1A4c	Emission calculation for off-road vehicles and other machinery was changed to a T3 methodology using the GEORG model, leading to lower emissions than in previous submissions where T1 default EFs were used.	Updated methodology and EF

### 3.2.9.8 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 3-80 will be explored.

**Table 3-80 – Planned improvements for category 1A4 – Other Sectors**

GHG source & sink category	Planned improvement
1A4a – Commercial/Institutional	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.
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*: Off-road Vehicles and Other Machinery, Airport and Military Vehicles

In 2014, no GHG emissions occurred in IPCC sub-category 1A5, hence, notation key *NO* is used. In 1990, 1A5 was responsible for 0.28% of GHG emissions from fuel combustion activities and represented around 0.23% of the total GHG emissions excluding LULUCF.

1A5 - *Other* related CO<sub>2</sub> emissions from liquid fuels have been identified as a key category in 1999.

Table 3-81 summarizes GHG emissions for category 1A5 – *Other*.

Table 3-81 – GHG emission trends in CO<sub>2</sub>e for category 1A5 – Other: 1990-2014

1A5 - Other												
GHG emissions by source & sink category (Gg)												
Year	1A5a - Stationary				1A5b - Mobile				1A5 - Other			
	Total CO <sub>2</sub> eq	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Total CO <sub>2</sub> eq	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Total CO <sub>2</sub> eq	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
1990	2.98	2.97	0.0002	0.0000	26.28	23.53	0.001	0.009	29.26	26.51	0.002	0.009
1991	2.98	2.97	0.0002	0.0000	26.29	23.54	0.001	0.009	29.27	26.51	0.002	0.009
1992	26.66	26.52	0.0034	0.0002	16.43	14.72	0.001	0.006	43.10	41.23	0.004	0.006
1993	23.50	23.37	0.0030	0.0002	14.24	12.75	0.001	0.005	37.74	36.12	0.004	0.005
1994	21.91	21.79	0.0028	0.0002	13.14	11.77	0.001	0.005	35.05	33.56	0.003	0.005
1995	10.64	10.59	0.0013	0.0001	5.48	4.90	0.000	0.002	16.11	15.49	0.002	0.002
1996	18.39	18.30	0.0023	0.0001	10.92	9.78	0.001	0.004	29.32	28.08	0.003	0.004
1997	22.89	22.78	0.0027	0.0001	10.95	9.81	0.001	0.004	33.85	32.59	0.003	0.004
1998	33.97	33.80	0.0041	0.0002	17.53	15.69	0.001	0.006	51.49	49.49	0.005	0.006
1999	62.93	62.61	0.0078	0.0004	35.06	31.40	0.002	0.012	98.00	94.01	0.010	0.013
2000	12.08	12.05	0.0009	0.0000	NO	NO	NO	NO	12.08	12.05	0.001	0.000
2001	24.10	24.04	0.0019	0.0000	NO	NO	NO	NO	24.10	24.04	0.002	0.000
2002	13.40	13.37	0.0010	0.0000	NO	NO	NO	NO	13.40	13.37	0.001	0.000
2003	3.14	3.13	0.0002	0.0000	NO	NO	NO	NO	3.14	3.13	0.000	0.000
2004	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2005	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2006	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2007	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2008	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2009	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2010	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2011	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2012	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2013	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2014	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Trend 1990-2014	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Source: Environment Agency

Notes:

CO<sub>2</sub> emissions do not include CO<sub>2</sub> emissions from biomass which are reported under Memo Items.

CH<sub>4</sub> emissions are converted in CO<sub>2</sub>e 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<sub>2</sub>O emissions are converted in CO<sub>2</sub>e 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 2014, 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 3-82.

##### 3.2.10.2.2.2 Methodology

The 2006 IPCC Guidelines Tier 2 approach has been applied to CO<sub>2</sub>, whereas the Tier 1 approach was applied to CH<sub>4</sub> and N<sub>2</sub>O.

**Table 3-82 – 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 <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Activity (GJ)	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
1990	45 728	65 040	5.00	0.10	318 580	73 871	4.15	28.60
1991	45 728	65 044	5.00	0.10	318 580	73 885	4.15	28.60
1992	364 308	72 788	9.37	0.54	199 112	73 910	4.15	28.60
1993	321 934	72 600	9.29	0.53	172 629	73 870	4.15	28.60
1994	300 654	72 491	9.24	0.52	159 329	73 846	4.15	28.60
1995	148 456	71 308	8.58	0.46	66 395	73 841	4.15	28.60
1996	252 683	72 413	9.19	0.52	132 457	73 851	4.15	28.60
1997	321 685	70 824	8.30	0.43	132 817	73 850	4.15	28.60
1998	473 779	71 342	8.59	0.46	212 480	73 857	4.15	28.60
1999	869 847	71 982	8.91	0.49	425 126	73 855	4.15	28.60
2000	185 497	64 943	5.00	0.10	NO	NO	NO	NO
2001	370 223	64 942	5.00	0.10	NO	NO	NO	NO
2002	205 847	64 957	5.00	0.10	NO	NO	NO	NO
2003	48 158	64 976	5.00	0.10	NO	NO	NO	NO
2004	NO	NO	NO	NO	NO	NO	NO	NO
2005	NO	NO	NO	NO	NO	NO	NO	NO
2006	NO	NO	NO	NO	NO	NO	NO	NO
2007	NO	NO	NO	NO	NO	NO	NO	NO
2008	NO	NO	NO	NO	NO	NO	NO	NO
2009	NO	NO	NO	NO	NO	NO	NO	NO
2010	NO	NO	NO	NO	NO	NO	NO	NO
2011	NO	NO	NO	NO	NO	NO	NO	NO
2012	NO	NO	NO	NO	NO	NO	NO	NO
2013	NO	NO	NO	NO	NO	NO	NO	NO
2014	NO	NO	NO	NO	NO	NO	NO	NO

Source: Environment Agency

### 3.2.10.2.2.3 Emission factors

Country specific CO<sub>2</sub> emission factors were applied to gas oil and LPG, whereas for CH<sub>4</sub> and N<sub>2</sub>O, default 2006 IPCC emission factors were used (Table 3-83).

**Table 3-83 – Emission factors for category 1A5 – Other**

1A5 - Other								
Emission Factors for 2014 (kg/TJ)								
Fuel	Fuel Type	CO <sub>2</sub>		CH <sub>4</sub>		N <sub>2</sub> O		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	73 874	CS	10.00	D	0.60	D	AEV 2006 IPCC GL
Diesel Oil	liquid	73 874	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 3-82

### **3.2.10.3 Mobile (1A5b)**

#### 3.2.10.3.1 Source category description

In 2014, no emissions from fuel combustion activities from 1A5b - Mobile were reported (notation key NO). In 1990, this category was responsible for 0.25% of GHG emissions from fuel combustion activities. With regard to total GHG emissions excluding LULUCF, the share was 0.20% in 1990.

#### 3.2.10.3.2 Methodological issues & time-series consistency

##### 3.2.10.3.2.1 Activity data

Fuel consumption data (diesel oil) is obtained from the national statistics institute and was attributed to this sub-category based on expert judgement. Activity data is listed in Table 3-82.

##### 3.2.10.3.2.2 Methodology

The 2006 IPCC Guidelines Tier 2 approach has been applied to CO<sub>2</sub>, whereas the Tier 1 approach was applied to CH<sub>4</sub> and N<sub>2</sub>O.

##### 3.2.10.3.2.3 Emission factors

Country-specific CO<sub>2</sub> emission factors have been applied to diesel oil, whereas for CH<sub>4</sub> and N<sub>2</sub>O, default 2006 IPCC emission factors were used (Table 3-83).

### **3.2.10.4 Uncertainties and time-series consistency**

For uncertainties on activity data and emission factors, please refer to section 1.7.

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**

No recalculations were done relevant to category *1A5 – Other*.

#### **3.2.10.7 Category-specific planned improvements including those in response to the review process**

No further improvements are planned.

### **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 2014, fugitive emissions from category *1B2 – Oil and natural gas and other emissions from energy production* were responsible for 0.41% of GHG emissions from the energy sector (0.19% in 1990) and represented 0.36% of the total GHG emissions excluding LULUCF (0.15% in 1990). Compared to 2013, fugitive GHG emissions decreased by 5.57%. Table 3-84 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 3-84 – GHG emission trends in CO<sub>2</sub>e for category 1B2 – Oil and natural gas and other emissions from energy production: 1990-2014**

1B2 - Oil and Natural Gas																
CO <sub>2</sub> e emissions (Gg)																
Year	1B2a - Oil				1B2b - Natural Gas				1B2c - Venting & Flaring				1B2d - Other			
	Total	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Total	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Total	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Total	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
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
Trend 1990-2014	NA	NA	NA	NA	98.45%	98.45%	98.45%	NA	NA	NA	NA	NA	NA	NA	NA	NA
Trend 2013-2014	NA	NA	NA	NA	-5.57%	-5.57%	-5.57%	NA	NA	NA	NA	NA	NA	NA	NA	NA

Source: Environment Agency

Notes: CH<sub>4</sub> emissions are converted in CO<sub>2</sub>e 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 3-85.

**Table 3-85 – Activity data for category 1B2 – Oil and natural gas and other emissions from energy production: 1990-2014**

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
28'119'435	31'177'039	44'596'356	45'132'516	50'018'454	49'248'164	51'513'517	48'083'276	45'774'534	46'592'327
2010	2011	2012	2013	2014					
50'108'059	43'235'365	44'010'941	37'284'498	35'310'029					

Source: STATEC: Statistical Yearbook, table A4200 (natural gas) and converted to the NCV basis.

#### 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<sub>2</sub>: ..... 8.8\*10<sup>-7</sup> Gg/10<sup>6</sup> m<sup>3</sup>
- Natural Gas Distribution - CO<sub>2</sub>: ..... 5.1\*10<sup>-5</sup> Gg/10<sup>6</sup> m<sup>3</sup>
- Natural Gas Transmission - CH<sub>4</sub>: ..... 4.8\*10<sup>-4</sup> Gg/10<sup>6</sup> m<sup>3</sup>
- Natural Gas Distribution - CH<sub>4</sub>: ..... 1.1\*10<sup>-3</sup> Gg/10<sup>6</sup> m<sup>3</sup>

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

For uncertainties on activity data and emission factors, please refer to section 1.7.

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 3-86 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, please refer to Chapter 10.

**Table 3-86 – Recalculations done since submission 2015v11**

GHG source & sink category	Revisions 2015v1 → 2016v1	Type of revision
1B2	AD for natural gas was revised due to a revised energy balance by the national statistics institute.	Updated AD

### 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 3-87 will be explored.

**Table 3-87 – 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 and Product Use (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 2014.

Emissions from this sector comprise emissions from the following categories: mineral products (2A), metal production (2C) and consumption of halocarbons (2F), SF<sub>6</sub> and N<sub>2</sub>O (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).

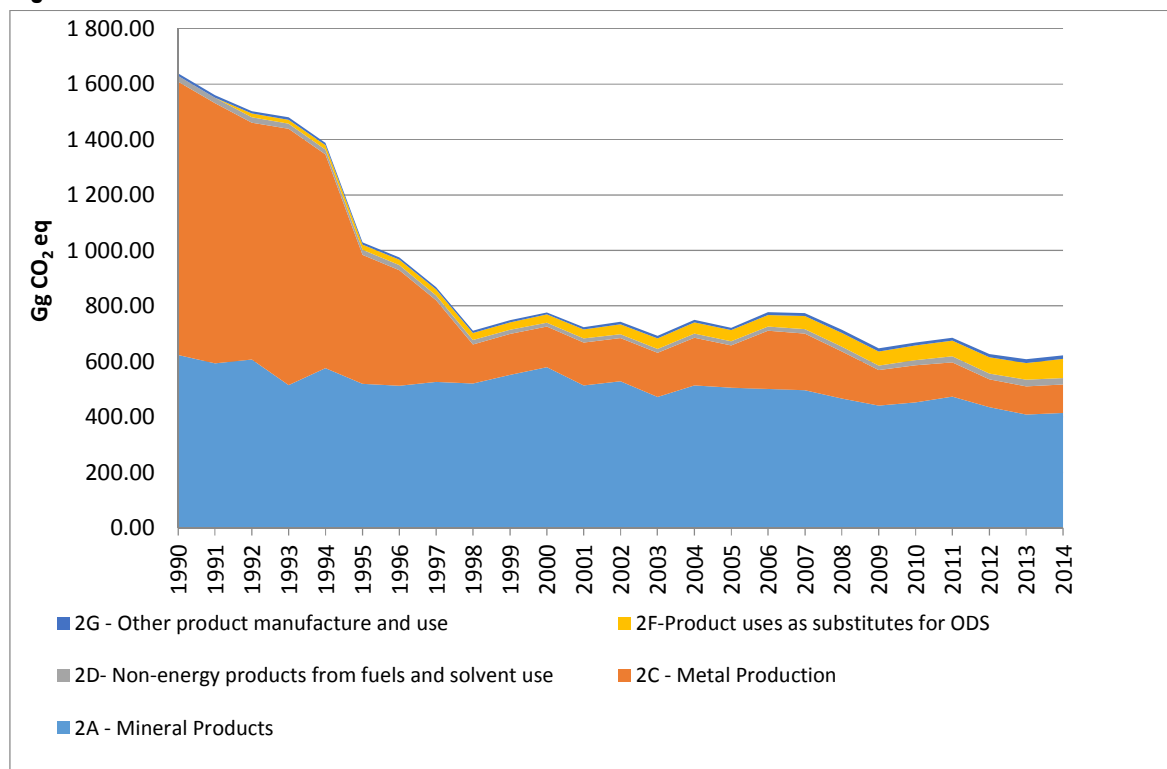
#### **4.1.1 Emission Trends**

This section briefly describes the emission trends from 1990 to 2014 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<sub>6</sub> (the fluorinated gases (HFCs and SF<sub>6</sub>) 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 62.1.3% between 1990 and 2014 (-66.84% for carbon dioxide but +23903% for F-gases). It is for IPCC Category 2C – *Metal Production* that CO<sub>2</sub> emissions have decreased the most over the period: -89.6%. For IPCC Category 2A – *Mineral Products* the decline is limited to -33.5% for CO<sub>2</sub> emissions.

**Figure 4-1 – GHG emission trends for CRF Sector 2 – Industrial Processes: 1990-2014**



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 2014. More explanations are presented in the subsequent sections detailing each of the sector source sub-categories.

Table 4-1 – GHG emission trends in CO<sub>2</sub>e for CRF Sector 2 – Industrial Processes: 1990-2014

2 - Industrial Processes												
GHG emissions by source & sink category (Gg CO <sub>2</sub> eq)												
Year	2A - Mineral Products				2C - Metal Production				2D- Non-energy products from fuels and solvent use			
	Total	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Total	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Total	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
1990	623.45	623.45	NO	NO	984.91	984.91	NO	NO	21.05	21.05	NO	NO
1991	592.76	592.76	NO	NO	937.74	937.74	NO	NO	20.58	20.58	NO	NO
1992	607.15	607.15	NO	NO	853.29	853.29	NO	NO	19.55	19.55	NO	NO
1993	515.03	515.03	NO	NO	923.19	923.19	NO	NO	18.53	18.53	NO	NO
1994	575.35	575.35	NO	NO	770.83	770.83	NO	NO	17.77	17.77	NO	NO
1995	519.11	519.11	NO	NO	465.38	465.38	NO	NO	18.38	18.38	NO	NO
1996	512.12	512.12	NO	NO	416.60	416.60	NO	NO	18.36	18.36	NO	NO
1997	525.97	525.97	NO	NO	294.10	294.10	NO	NO	17.58	17.58	NO	NO
1998	520.30	520.30	NO	NO	140.69	140.69	NO	NO	16.79	16.79	NO	NO
1999	551.34	551.34	NO	NO	147.70	147.70	NO	NO	15.67	15.67	NO	NO
2000	579.74	579.74	NO	NO	146.05	146.05	NO	NO	14.22	14.22	NO	NO
2001	513.12	513.12	NO	NO	154.76	154.76	NO	NO	14.70	14.70	NO	NO
2002	528.32	528.32	NO	NO	155.40	155.40	NO	NO	14.61	14.61	NO	NO
2003	471.66	471.66	NO	NO	158.94	158.94	NO	NO	13.97	13.97	NO	NO
2004	513.37	513.37	NO	NO	172.45	172.45	NO	NO	14.55	14.55	NO	NO
2005	504.99	504.99	NO	NO	152.92	152.92	NO	NO	15.23	15.23	NO	NO
2006	500.63	500.63	NO	NO	209.79	209.79	NO	NO	14.80	14.80	NO	NO
2007	496.26	496.26	NO	NO	203.49	203.49	NO	NO	16.86	16.86	NO	NO
2008	466.41	466.41	NO	NO	169.30	169.30	NO	NO	17.03	17.03	NO	NO
2009	440.16	440.16	NO	NO	128.66	128.66	NO	NO	16.60	16.60	NO	NO
2010	452.57	452.57	NO	NO	133.61	133.61	NO	NO	18.22	18.22	NO	NO
2011	472.70	472.70	NO	NO	123.86	123.86	NO	NO	22.18	22.18	NO	NO
2012	434.94	434.94	NO	NO	100.23	100.23	NO	NO	21.47	21.47	NO	NO
2013	408.66	408.66	NO	NO	101.59	101.59	NO	NO	24.05	24.05	NO	NO
2014	414.59	414.59	NO	NO	102.46	102.46	NO	NO	23.30	23.30	NO	NO
Trend 2013-2014	1.45%	1.45%	NA	NA	0.86%	0.86%	NA	NA	-3.12%	-3.12%	NA	NA
Trend 1990-2014	-33.50%	-33.50%	NA	NA	-89.60%	-89.60%	NA	NA	10.66%	10.66%	NA	NA

2 - Industrial Processes													
GHG emissions by source & sink category (Gg CO <sub>2</sub> 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 <sub>2</sub> O	Total	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	F-gases
1990	0.00	0.00	NO	9.23	0.00	NO	0.33	8.91	1 638.65	1 629.42	NO	8.91	0.33
1991	0.00	0.00	NO	8.93	0.00	NO	0.35	8.58	1 560.02	1 551.09	NO	8.58	0.35
1992	13.69	13.69	NO	8.60	0.00	NO	0.37	8.23	1 502.29	1 479.99	NO	8.23	14.06
1993	14.71	14.71	NO	8.31	0.00	NO	0.40	7.91	1 479.78	1 456.76	NO	7.91	15.11
1994	16.04	16.04	NO	8.03	0.00	NO	0.43	7.60	1 388.03	1 363.96	NO	7.60	16.47
1995	17.97	17.97	NO	8.67	0.00	NO	1.39	7.28	1 029.52	1 002.87	NO	7.28	19.36
1996	19.71	19.71	NO	8.51	0.00	NO	1.56	6.95	975.30	947.08	NO	6.95	21.26
1997	22.13	22.13	NO	8.32	0.00	NO	1.70	6.63	868.10	837.65	NO	6.63	23.82
1998	24.54	24.54	NO	8.04	0.00	NO	1.74	6.30	710.35	677.78	NO	6.30	26.28
1999	26.38	26.38	NO	7.78	0.00	NO	1.83	5.95	748.87	714.71	NO	5.95	28.21
2000	29.13	29.13	NO	7.52	0.00	NO	1.93	5.59	776.66	740.00	NO	5.59	31.06
2001	33.10	33.10	NO	7.76	0.00	NO	2.54	5.22	723.44	682.58	NO	5.22	35.64
2002	35.92	35.92	NO	8.41	0.00	NO	3.15	5.26	742.66	698.34	NO	5.26	39.06
2003	38.28	38.28	NO	8.82	0.00	NO	3.73	5.09	691.67	644.57	NO	5.09	42.01
2004	40.34	40.34	NO	8.89	0.00	NO	4.28	4.61	749.59	700.36	NO	4.61	44.62
2005	39.38	39.38	NO	9.12	0.00	NO	4.85	4.27	721.65	673.15	NO	4.27	44.24
2006	42.38	42.38	NO	9.83	0.00	NO	5.27	4.56	777.42	725.22	NO	4.56	47.65
2007	47.08	47.08	NO	10.58	0.00	NO	5.69	4.88	774.26	716.60	NO	4.88	52.77
2008	49.55	49.55	NO	11.43	0.00	NO	6.10	5.33	713.71	652.74	NO	5.33	55.64
2009	50.42	50.42	NO	11.18	0.00	NO	6.49	4.69	647.02	585.41	NO	4.69	56.92
2010	53.13	53.13	NO	10.45	0.00	NO	6.87	3.58	667.98	604.40	NO	3.58	60.00
2011	56.03	56.03	NO	10.72	0.00	NO	7.31	3.41	685.50	618.74	NO	3.41	63.34
2012	58.42	58.42	NO	10.96	0.00	NO	7.68	3.28	626.03	556.64	NO	3.28	66.10
2013	59.35	59.35	NO	13.90	2.56	NO	8.05	3.28	607.54	534.30	NO	3.28	69.97
2014	68.29	68.29	NO	12.95	1.71	NO	8.44	2.80	621.58	540.34	NO	2.80	78.44
<b>Trend 2013-2014</b>	15.06%	15.06%	NA	-6.82%	-33.46%	NA	4.89%	-14.75%	2.31%	1.13%	NA	-14.75%	12.11%
<b>Trend 1990-2014</b>	95515130.14%	95515130.14%	NA	40.26%	NA	NA	2484.63%	-68.58%	-62.07%	-66.84%	NA	-68.58%	23902.95%

Source: Environment Agency

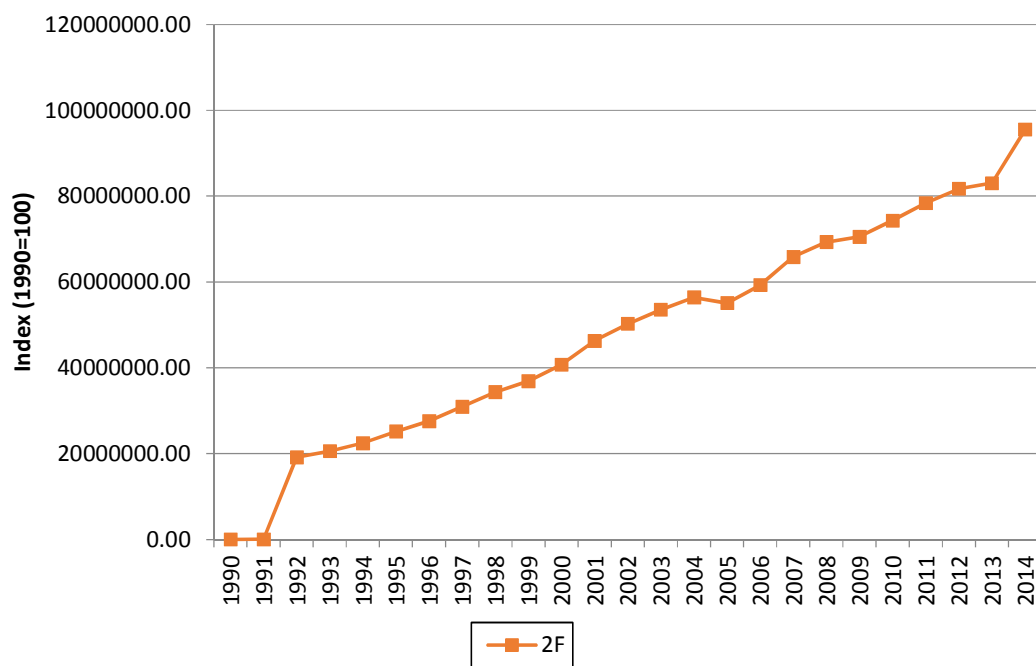
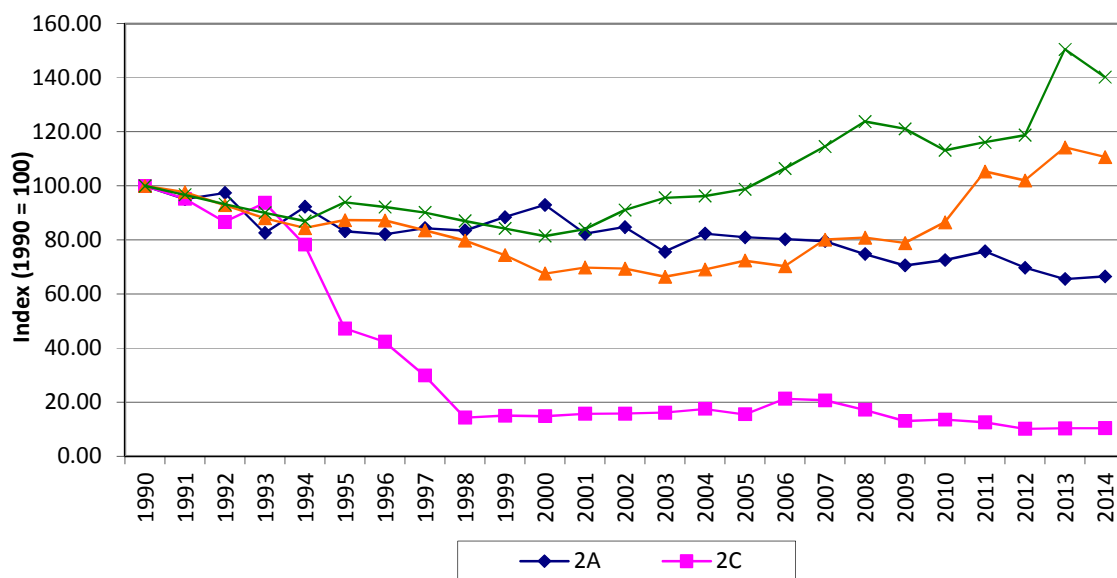
Notes:

CH<sub>4</sub> emissions are converted in CO<sub>2</sub>e 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.

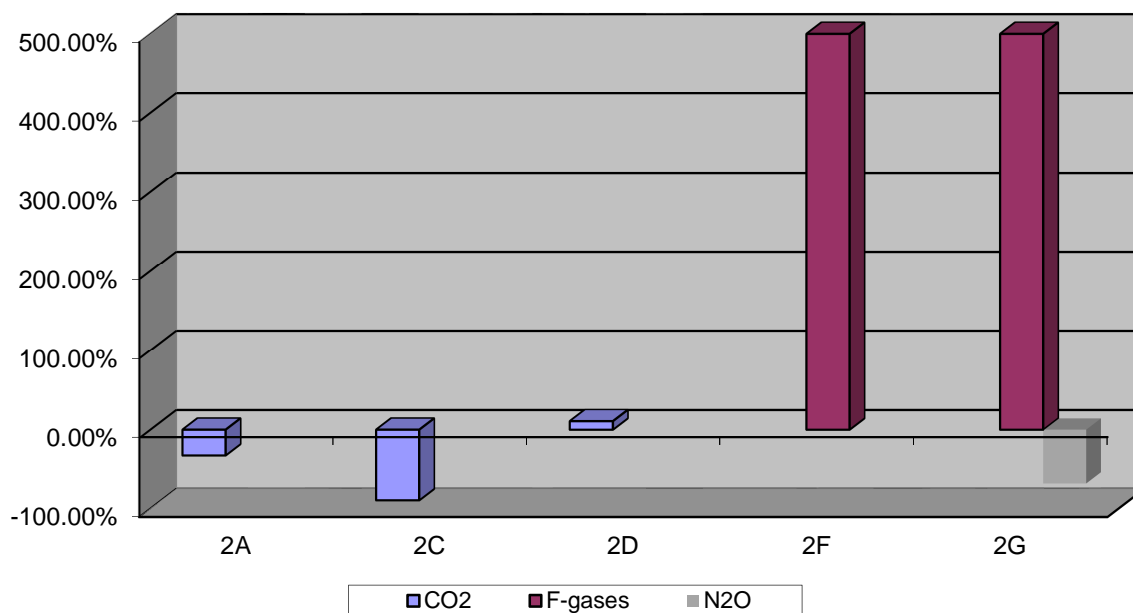
N<sub>2</sub>O emissions are converted in CO<sub>2</sub>e by multiplying the emissions by 310, i.e. the global warming potential (GWP) value for nitrous oxide based on the effects of GHG over a 100-year time horizon.

The F-gases are those not covered by the Montreal Protocol, i.e. HFCs, PFCs and SF6 expressed in CO<sub>2</sub>e 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: 1990-2014



**Figure 4-3 – GHG emission trends in % for CRF Sector 2 – Industrial Processes: 1990-2014**

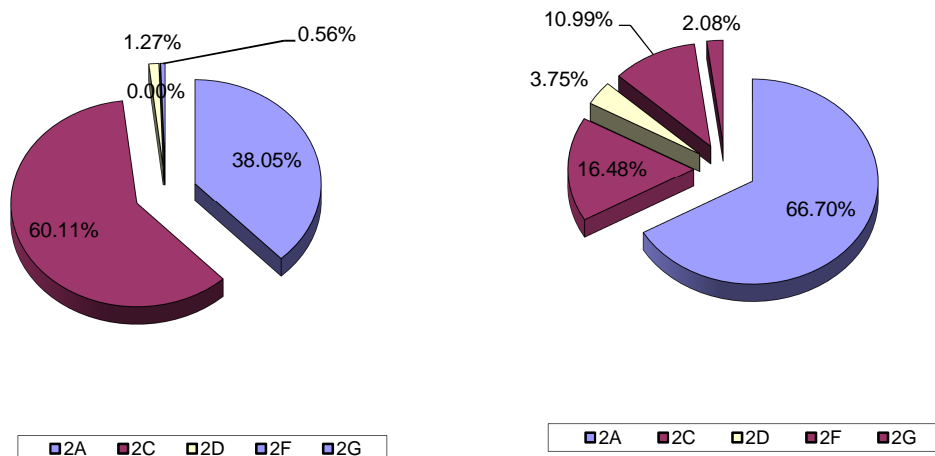


The emission trends briefly described above led to a significant change in the composition of industrial processes' GHG emissions, as shown in Figure 4-4.

**Figure 4-4 – IPCC Categories weights in GHG emissions for CRF Sector 2 – Industrial Processes: 1990 and 2014**

1990

2014



#### 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						
Key sources						
IPCC Category	Category Name	GHG	LA excl. LULUCF	LA incl. LULUCF	TA excl. LULUCF	TA incl. LULUCF
2A1	Cement Production	CO <sub>2</sub>	90-12	90-12	X	X
2A7	Other - Glass Production	CO <sub>2</sub>	95-12		X	X
2C1	Iron & Steel Production	CO <sub>2</sub>	90-12	90-01, 06-08	X	X
2F	Consumption of Halocarbons & SF6	F-gases	03-12		X	X

Source: Environment Agency

Notes: LA = Level Assessment including respectively excluding LULUCF

TA = Trend Assessment 2008 including respectively excluding 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<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O**

GHG source & sink category	Description	Status		
		CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
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 - zinc production	NO	NO	NO
2.C.7	metal production - other	NO	NO	NO
2.D.1	non-energy products from fuels and solvent use - lubricant use	X		
2.D.2	non-energy products from fuels and solvent use - paraffin wax use	X		
2.D.3	non-energy products from fuels and solvent use - other	X		
2.D.3	solvent use	X	NO	NO
2.D.3	road paving with asphalt	NO	NO	NO
2.D.3	asphalt roofing	NO	NO	NO



GHG source & sink category	Description	Status		
		CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
2.D.3	other (please specify)	NO	NO	NO
2.G	other product manufacture and use	NO	NO	X
2.G.3	other product manufacture and use - N <sub>2</sub> O from product uses	NO	NO	X
2.G.3.a	Medical applications	NO	NO	X
2.G.3.b	other	NO	NO	NO
	propellant for pressure and aerosol products	NO	NO	NO
	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<sub>6</sub> and NF<sub>3</sub>**

GHG source & sink category	Description	Status			
		HFCs	PFCs	SF <sub>6</sub>	NF <sub>3</sub>
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	SF <sub>6</sub> 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 2014, this source category was responsible for 66.70% of CO<sub>2</sub> emissions from industrial processes – but only 38.05% in 1990 – and for 4.03% of the total CO<sub>2</sub> emissions estimated for Luxembourg. It represented 3.70% of the total GHG emissions in CO<sub>2</sub>e (excluding LULUCF) in 2014 and 4.83% in 1990. Compared to 2013, emissions increased by 1.45% to attain the level of 414.59 Gg CO<sub>2</sub> in 2014. Compared to 1990, emissions decreased by 33.50%.

### 4.2.1 Cement Production (2.A.1)

#### 4.2.1.1 Source category description

In 2014, clinker production was responsible for 65.42% of CO<sub>2</sub> emissions from industrial processes – but only 34.98% in 1990 – and for 3.43% of the total CO<sub>2</sub> emissions estimated for Luxembourg. It represented 3.16% of the total GHG emissions in CO<sub>2</sub>e (excluding LULUCF). Compared to 2013, emissions decreased by 1.64% to attain the level of 353.51 Gg CO<sub>2</sub> in 2014. Compared to 1990, emissions decreased by 30.24%.

2A1 - *Cement Production* is a key source with regard to CO<sub>2</sub> 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<sub>3</sub>), is calcined to produce lime (CaO) and CO<sub>2</sub> 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

For the estimation of CO<sub>2</sub> emissions, the ETS 2007 method using clinker production data is applied:

$$CO_2 \text{ Emissions} = EF_{clinker} \bullet CF_{clinker} \bullet \text{Clinker Production}$$

The conversion factor (CF<sub>clinker</sub>) 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.

Emission estimates from the Tier 2 method, as well as activity data and IEFs, are summarized in Table 4-5.

**Table 4-5 – CO<sub>2</sub> emissions trend, activity data and IEFs for IPCC sub-category 2A1 – Cement Production: 1990-2014**

<b>2A1 - Clinker Production</b>			
<i>Activity data, emissions and implied emission factors</i>			
<b>Year</b>	<b>AD</b>	<b>CO<sub>2</sub></b>	<b>IEF</b>
	<b>t</b>	<b>Gg</b>	<b>kg CO<sub>2</sub> / t clinker</b>
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	353.51	483.55
<b>Trend 2013-2014</b>	-1.64%	-3.26%	-1.65%
<b>Trend 1990-2014</b>	-30.24%	-37.97%	-11.08%

Sources: AD: plant operator ; CO<sub>2</sub> and IEF: Environment Agency

#### 4.2.1.2.3 Emission factor

According to 2007 ETS Tier 3 method, the emission factor is based on the CaO and MgO content of the clinker:

$$EF_{clinker} = 0.785 \bullet CaO \text{ Content} + 1.092 \bullet MgO \text{ Content (Weight Fraction in Clinker)}$$

**Table 4-6 – CaO and MgO contents in %**

Year	CaO Content	MgO Content
	weight %	weight %
1990	67.72%	1.12%
1995	67.46%	1.02%
2000	67.16%	0.98%
2005	66.49%	0.88%
2008	66.28%	0.90%
2009	66.78%	0.89%
2010	66.59%	0.84%
2011	66.84%	0.83%
2012	65.93%	1.22%
2013	65.93%	1.22%
2014	67.11%	1.43%
Source: plant operator		

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 4-7).

**Table 4-7 – Effective and interpolated CaO content in % and EFs: 1990-2014**

2A1 - Cement Production						
CaO content & emission factors						
Year	CaO (%)	CaO (%)	MgO (%)	MgO (%)	EF	CF
	operator	interpolation	operator	interpolation	kg CO <sub>2</sub> / 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
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<sub>3</sub> and MgCO<sub>3</sub> 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

Table 4-8 gives the error values which are assumed on the various calculation parameters for the uncertainty assessment.

**Table 4-8 – Error values (%) for uncertainty assessment**

Step	Error (%) IPCC GPG 2000 Table 3.1 (Tier 2)	Error (%) Plant-specific estimation
1) Production data	1-2	1.5
2) Assume 100% carbonate source from CaCO <sub>3</sub>	1-3	2
3) CaO chemical analysis	1-2	1.5

Combined resulting errors (uncertain quantities are to be combined by multiplication):

- Activity data uncertainty ..... 1.5 %
- Emission factor uncertainty ..... 2.5 %
- Emissions uncertainty ..... 2.9 %

#### 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<sub>2</sub>/t clinker.

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

No recalculations were done since the last submission.

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 2014, glass production was responsible for 11.30% of CO<sub>2</sub> emissions from industrial processes – but only 3.29% in 1990 – and for 0.59% of the total CO<sub>2</sub> emissions estimated for Luxembourg. It represented 0.54% of the total GHG emissions in CO<sub>2</sub>e (excluding LULUCF). Compared to 2013, emissions increased by 41.27% to attain the level of 61.07 Gg CO<sub>2</sub> in 2014. During the year 2013, part of the glass production was shut down do to maintenance. In 2014, production levels return to normal, explaining the emission increase of over 40%. Compared to 1990, emissions increased by 14.04%.

2.A.3 - *Glass Production* is a key source with regard to CO<sub>2</sub> 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<sub>2</sub> 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 4-9).

###### 4.2.3.2.2 Methodology

A country specific (CS) methodology is applied:

$$CO_2 \text{ emissions} = EF_{\text{glass}} \bullet \text{Glass Production}$$

Estimates from the CS method, as well as activity data and IEFs, are summarized in Table 4-9.

**Table 4-9 – CO<sub>2</sub> emission trend, activity data and IEFs for IPCC sub-category 2.A.3 – Other – Glass Production: 1990-2014**

<b>2A7 - Other - Glass Production</b>			
<i>Activity data, emissions and implied emission factors</i>			
<b>Year</b>	<b>AD</b>	<b>CO<sub>2</sub></b>	<b>IEF</b>
	<b>t</b>	<b>Gg</b>	<b>kg CO<sub>2</sub> / t glass</b>
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	61.78	142.00
2006	435 806	61.88	142.00
2007	443 094	62.92	142.00
2008	440 538	62.56	142.00
2009	437 319	62.10	142.00
2010	430 140	61.08	142.00
2011	433 676	61.58	142.00
2012	423 081	60.08	142.00
2013	304 453	43.23	142.00
2014	430 098	61.07	142.00
<b>Trend 2013-2014</b>	41.27%	41.28%	0.00%
<b>Trend 1990-2014</b>	14.01%	14.01%	0.00%

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<sub>2</sub> as loss of ignition. There is no indication of any change in product quality or batch composition over time and hence the emission factor is kept constant the whole time.

$$EF_{glass} = 142 \text{ kg CO}_2/\text{t glass}$$

The calculated specific EF is consistent with the calculated value for 2013 according to the 2007 ETS Guidelines carbonates method. For 2013, plant-specific EF's of 139 and 137 kg CO<sub>2</sub>/t glass were determined based on the carbonate contents in the raw materials and the activity data for plant 1 and plant 2.

#### **4.2.3.3 Uncertainties and time-series consistency**

Estimations of uncertainties are based on expert judgement:

- Activity data uncertainty ..... 2.0 %
- Emission factor uncertainty ..... 5.0 %
- Cumulative emission uncertainty ..... 5.4 %

#### **4.2.3.4 Source-specific QA/QC and verification**

The calculated CO<sub>2</sub> emission is consistent with the calculated value according to the 2007 ETS Guidelines' carbonates method.

- Link to soda ash use

#### **4.2.3.5 Category-specific recalculations including changes made in response to the review process**

No revisions and recalculations have been done since the last submission.

#### **4.2.4 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)**

##### **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*.

The amount of soda ash used in 2013 in the glass production was 53849 t (Source: verified ETS data). In 2014, the use of soda ash amounted to 71554 t. There is no other soda ash use in Luxembourg.



#### **4.2.5.3 Non Metallurgical Magnesia Production (2.A.4.c)**

This source category does not exist in Luxembourg.

#### **4.2.5.4 Other (2.A.4.d)**

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<sup>108</sup> (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 2014, iron and steel production was responsible for 18.96% of CO<sub>2</sub> emissions from industrial processes – but 60.45% in 1990 – and for 0.99% of the total CO<sub>2</sub> emissions estimated for Luxembourg. It represented 0.91% of the total GHG emissions in CO<sub>2</sub>e (excluding LULUCF). Compared to 2013, emissions increased by 0.86% to attain the level of 102.46.2 Gg CO<sub>2</sub> in 2014. Compared to 1990, emissions decreased by 89.60% 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<sub>2</sub> emissions is provided in Table 4-10.

*2C1 – Iron and Steel Production* is a key source with regard to CO<sub>2</sub> emissions. It has been a key source since 1990: see Table 4-2 in Section 4.1.2.

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<sup>108</sup> Accounted for under IPCC Category 1A – Fuel Combustion Activities. See also Section 4.4.1.3 below.

**Table 4-10 – CO<sub>2</sub> emissions trend, activity data and IEFs for category 2C1 – Iron and Steel Production: 1990-2014**

<b>2C1 - Iron &amp; Steel Production</b>					
<b>Emissions, AD, IEFs</b>					
<b>Year</b>	<b>CO<sub>2</sub> (Gg)</b>	<b>BOF (t)</b>	<b>EAF (t)</b>	<b>Total (t)</b>	<b>IEF kg CO<sub>2</sub>/t steel</b>
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
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 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. In 2013 and 2014, only two of the three electric arc furnaces (*EAF*) were in operation.

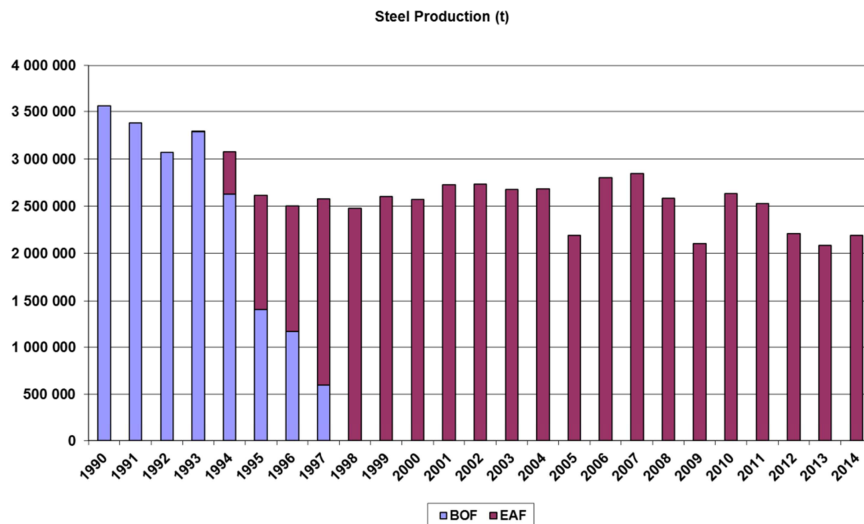
A simplified country-specific methodology is used for the years 1993 to 2003 (as the first EAF was only introduced in 1993). It is important to mention that the base year 1990 is not concerned by this simplified methodology. In 1990, only blast furnaces were operated. Concerning time-series consistency, 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:  $E = (C_{Carbon} + C_{Anthracite}) * 3.664 + E_{Electrodes} + E_{Pig\ iron} + E_{Petroleum\ coke} + E_{CaC_2} + E_{Scrap} - E_{Steel}$

$E_i = A_{Di} * E_{Fi}$  with  $i$  = electrodes, pig iron, petroleum coke,  $CaC_2$

All materials introduced in the furnace and containing carbon are considered (carbon, anthracite, electrodes, pig iron, petroleum coke,  $CaC_2$  and scrap) and it is assumed that the carbon content of the steel output equals to the scrap input.

**Figure 4-5 – Steel production according to BOF and EAF: 1990-2014**



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<sub>2</sub> 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<sub>2</sub>.

#### 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<sub>2</sub> 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-hearth 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.

#### 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 4-11 – Background data for the calculation of CO<sub>2</sub> emissions – Sinter Plant**

Raw material	Tonnes (dry)	% C	Gg CO <sub>2</sub>
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:

$$CO_2 \text{ Emissions}_{SP} = EF_{SP} \bullet \text{Sinter Production}$$

##### 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.

$$Emissions_{BF} = E_{Iron} = (C_{Reducing \text{ Agent}} + C_{Ore} - C_{Iron}) \bullet 44/12$$

$$Emissions_{BOF} = E_{Steel} = (C_{Iron} + C_{Scrap} + C_{AddBOF} - C_{Steel}) \bullet 44/12$$

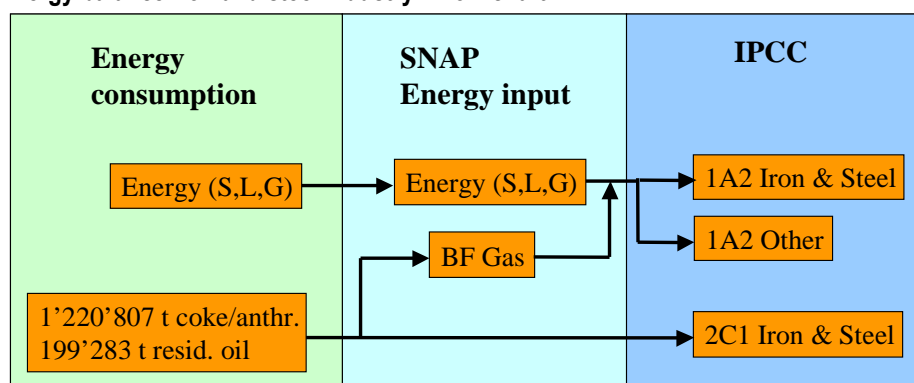
With:

$C_{Reducing \text{ Agent}}$	= 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 ( $C_{Reducing \text{ Agent}}$ ) 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 4-12), 160.05 Gg carbon (C) serves as reducing agent in the blast furnace.

Table 4-12 – 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 <sub>2</sub> / 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:



$$CO_2 \text{ Emissions}_{BF} = EF_{BF} \bullet \text{Pig Iron Production}$$

$$CO_2 \text{ Emissions}_{BOF} = EF_{BOF} \bullet \text{Steel Production}$$

#### 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.

$$E = (C_{Carbon} + C_{Anthracite}) \bullet 3.664 + E_{Electrodes} + E_{Pig\ iron} + E_{Petroleum\ coke} + E_{CaC_2} + E_{Scrap} - E_{Steel}$$

$$E_i = AD_i \bullet EF_i \quad \text{with } i = \text{electrodes, pig iron, petroleum coke, CaC}_2$$

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.

The resulting emissions for the steel production are:

$$2014 - CO_2 \text{ Emissions}_{EAF} = 102.46 \text{ Gg CO}_2$$

$$2013 - CO_2 \text{ Emissions}_{EAF} = 101.59 \text{ Gg CO}_2$$

$$2012 - CO_2 \text{ Emissions}_{EAF} = 100.23 \text{ Gg CO}_2$$

$$2011 - CO_2 \text{ Emissions}_{EAF} = 123.86 \text{ Gg CO}_2$$

$$2010 - CO_2 \text{ Emissions}_{EAF} = 133.61 \text{ Gg CO}_2$$

$$2009 - CO_2 \text{ Emissions}_{EAF} = 112.66 \text{ Gg CO}_2$$

$$2008 - CO_2 \text{ Emissions}_{EAF} = 134.69 \text{ Gg CO}_2$$

$$2007 - CO_2 \text{ Emissions}_{EAF} = 162.22 \text{ Gg CO}_2$$

$$2006 - CO_2 \text{ Emissions}_{EAF} = 170.49 \text{ Gg CO}_2$$

$$2005 - CO_2 \text{ Emissions}_{EAF} = 119.13 \text{ Gg CO}_2$$

$$2004 - CO_2 \text{ Emissions}_{EAF} = 152.45 \text{ Gg CO}_2$$

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:

$$CO_2 \text{ Emissions}_{SEAF} = EF_{SEAF} \bullet \text{Steel Production}$$

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.

$$E_{Primus} = (C_{Raw \text{ materials}} + C_{Electrodes} + C_{Carbon} + C_{Anthracite} - C_{Products}) \times 44/12$$

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:

$$Emissions_{PRIMUS} = 16.00 \text{ Gg CO}_2$$

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 4-13) and the average ratio of the CO<sub>2</sub> emissions per carbon consumption for the years 2005-2008.

**Table 4-13 – 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
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<sub>2</sub> emissions and the production data in 1990. The EF is kept constant for the subsequent years 1991 to 1997: see Table 4-14.

**Table 4-14 – EFs for SP, BF and BOF**

Production (1990)	Emissions (1990)	EF
4 804 000 t sinter	380.44 Gg CO <sub>2</sub>	EF <sub>SP</sub> = 79.19 kg CO <sub>2</sub> / t sinter
2 645 200 t iron	200.00 Gg CO <sub>2</sub>	EF <sub>BF</sub> = 75.61 kg CO <sub>2</sub> / t iron
3 506 230 t steel	404.48 Gg CO <sub>2</sub>	EF <sub>BOF</sub> = 115.36 kg CO <sub>2</sub> / t steel

For **EAF**, the EF<sub>EAF</sub> is calculated from the determined CO<sub>2</sub> 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 4-15.

**Table 4-15 – EFs for EAF**

Year	Production t steel	Emissions Gg CO <sub>2</sub>	EF <sub>EAF</sub> (kg CO <sub>2</sub> / 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

The calculated emission factor for steel production in 2004 (EF<sub>EAF</sub> = 56.80 kg CO<sub>2</sub> / 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).

For the PRIMUS® process, the implied emission factors EF<sub>PRIMUS</sub>, for the years 2005-2009, are calculated from the determined CO<sub>2</sub> emissions and the introduced filter dust (Table 4-16).

**Table 4-16 – AD, emissions and IEF for Primus**

Year	Filter dust (t )	Emissions (Gg CO <sub>2</sub> )	EF PRIMUS (Mg CO <sub>2</sub> / 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
<u>Note:</u> Facility shut down in 2009			

#### 4.4.1.3 Uncertainties and time-series consistency

Table 4-17 gives the error values which are assumed on the various calculation parameters for the uncertainty assessment.

**Table 4-17 – Error values (%) for uncertainty assessment**

Step	Error (%)	Error (%)
	IPCC GPG 2000 Chap. 3.1.3.1	Plant-specific estimation
1) Amount of reducing agent for iron production	5	5
2) Pig iron activity data / Steel activity data	a few	2
3) Carbon content of pig iron and iron ore (plant-specific data are available)	5	5
4) emission factors uncertainties	5	5

Combined resulting errors (uncertain quantities are to be combined by multiplication):

- Emissions uncertainty (1990: 1), 2), 3), 4) ) 8.9 %
- Emissions uncertainty (2004: 2), 4)..... 5.4 %

#### 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 ( $EF_{\text{EAF}} = 56.80 \text{ kg CO}_2 / \text{t steel}$ ) 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**

No revisions and recalculations have been done since the last submission.

#### **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 2014, this source category was responsible for 3.75% of CO<sub>2</sub> emissions from industrial processes – but only 1.28% in 1990 – and for 0.26% of the total CO<sub>2</sub> emissions estimated for Luxembourg. It represented 0.24% of the total GHG emissions in CO<sub>2</sub>e (excluding LULUCF) in 2014 and 0.24% in 1990. Compared to 2013, emissions decreased by 3.12% to attain the level of 23.30 Gg CO<sub>2</sub> in 2014. Compared to 1990, emissions increased by 10.66%.

### **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 2014, this source category was responsible for 0.04% of the total CO<sub>2</sub> emissions estimated for Luxembourg. It represented 0.04% of the total GHG emissions in CO<sub>2</sub>e (excluding LULUCF) in 2014 and 0.05% in 1990. Compared to 2013, emissions decreased by 5.60% to attain the level of 4.37 Gg CO<sub>2</sub> in 2014. Compared to 1990, emissions decreased by 29.56%.

An overview of the lubricant related CO<sub>2</sub> emissions is provided in Table 4-18.

Table 4-18 – Activity data and CO<sub>2</sub> emissions from lubricant use: 1990-2014.

<b>2D1 - Lubricant Use</b>		
<b>Activity data, emissions</b>		
<b>Year</b>	<b>AD</b>	<b>CO<sub>2</sub></b>
	<b>t</b>	<b>Gg</b>
1990	10524.00	6.20
1991	10696.00	6.31
1992	10199.00	6.01
1993	9655.00	5.69
1994	10004.00	5.90
1995	10223.00	6.03
1996	10175.00	6.00
1997	9038.00	5.33
1998	9061.00	5.34
1999	7648.00	4.51
2000	7102.00	4.19
2001	6745.00	3.98
2002	7067.00	4.17
2003	6645.00	3.92
2004	5040.00	2.97
2005	6153.00	3.63
2006	4961.00	2.93
2007	4825.00	2.84
2008	4103.00	2.42
2009	3416.00	2.01
2010	3729.00	2.20
2011	8731.00	5.15
2012	7572.00	4.46
2013	7853.00	4.63
2014	7413.00	4.37
<b>Trend</b>		
<b>2013-2014</b>	-5.60%	-5.60%
<b>Trend</b>		
<b>1990-2014</b>	-29.56%	-29.56%

Sources: AD: STATEC ; CO<sub>2</sub>: 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 2014 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:

- 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

Table 4-19 summarizes the recalculations that have occurred since the last submission. For the quantitative aspect of these recalculations, please refer to Chapter 10.

**Table 4-19 - Recalculations done since submission 2015v1**

GHG source & sink category	Revisions 2015v1 → 2016v1	Type of revision
2D1	Relocation based on update reporting guidelines and CRF tables Methodology adapted to IPCC 2006 guidelines	Updated methodology



#### **4.5.1.6 Category-specific planned improvements including those in response to the review process**

There are currently no planned improvements for this sub-category.

### **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 2014, this source category was responsible for 0.02% of the total CO<sub>2</sub> emissions estimated for Luxembourg. It represented 0.02% of the total GHG emissions in CO<sub>2</sub>e (excluding LULUCF) in 2014 and 0.002% in 1990. Compared to 2013, emissions decreased by 36.30% to attain the level of 1.7 Gg CO<sub>2</sub> in 2014. Compared to 1990, emissions increased by 707.35%.

An overview of the paraffin wax related CO<sub>2</sub> emissions is provided in Table 4-20.

Table 4-20 – Activity data and GHG emissions from paraffin wax use: 1990-2014

<b>2D2 - Paraffin Wax Use</b>		
<b>Activity data, emissions</b>		
<b>Year</b>	<b>AD</b>	<b>CO<sub>2</sub></b>
	<b>t</b>	<b>Gg</b>
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
<b>Trend</b>		
<b>2013-2014</b>	-36.30%	-36.30%
<b>Trend</b>		
<b>1990-2014</b>	707.35%	707.35%

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 (2006 IPCC GLs, Chapter 5 and Table 5.3., p. 5.11) 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:

- 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**

A revision concerning the activity and emissions for the years 1990 to 2014 has 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.

**Table 4-21– Recalculations done since submission 2015v1**

GHG source & sink category	Revisions 2015v1 → 2016v1	Type of revision
2D2	Determination of the activity data and emissions for the years 1990 to 2014	New category calculations

### **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<sub>2</sub>.

For more details on categories where emissions are not occurring and categories that are not estimated or included elsewhere, see section Table 4-23.

##### **4.5.3.1.2 Emission Trends**

In 2014, this source category was responsible for 0.2% of the total CO<sub>2</sub> emissions estimated for Luxembourg. Furthermore, in 2014, 0.18% of total GHG emissions (excluding LULUCF) in Luxembourg originated from *Solvent and Other Product Use*, compared to 0.19% in 1990. Compared to 2013, GHG emissions from *Solvent and Other Product Use* decreased by 14%.

Figure 4-7 - Emissions and trend from 1990 – 2014 by Sub-Categories of 3 - Solvent and Other Product Use. Figure 4-7 and Table 4-22 present the trend in total greenhouse gas emissions by subcategories.

Figure 4-7 - Emissions and trend from 1990 – 2014 by Sub-Categories of 3 - Solvent and Other Product Use.

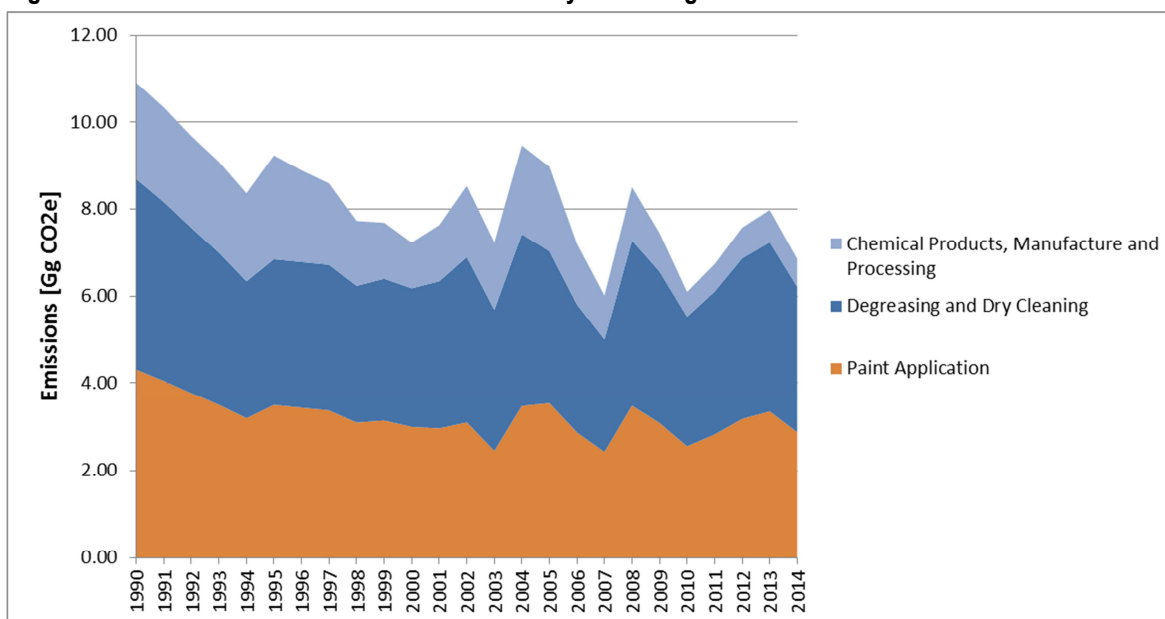


Table 4-22 - Emissions and trend from 1990 – 2014 by Sub-Categories of 3 - Solvent and Other Product Use.

GHG	2.D.3.1			
	Other – Solvent use	Paint Application	Degreasing and Dry Cleaning	Chemical Products, Manufacture and Processing
	Gg of CO <sub>2</sub> eq			
1990	15.41	4.31	4.38	2.22
1991	14.80	4.05	4.12	2.18
1992	14.02	3.76	3.81	2.11
1993	13.29	3.50	3.50	2.09
1994	12.33	3.19	3.15	2.02
1995	13.68	3.49	3.36	2.39
1996	13.41	3.43	3.35	2.11
1997	13.17	3.37	3.35	1.87
1998	12.07	3.09	3.14	1.49
1999	12.24	3.14	3.26	1.29
2000	11.72	3.00	3.18	1.05
2001	12.25	2.96	3.38	1.29
2002	13.56	3.10	3.80	1.64
2003	11.40	2.45	3.24	1.55
2004	14.99	3.47	3.96	2.04
2005	14.30	3.54	3.50	1.95
2006	11.64	2.87	2.94	1.39
2007	9.87	2.43	2.57	1.02

GHG	2.D.3.1			
	Other – Solvent use	Paint Application	Degreasing and Dry Cleaning	Chemical Products, Manufacture and Processing
2008	14.17	3.48	3.80	1.23
2009	12.60	3.09	3.48	0.89
2010	10.47	2.56	2.97	0.57
2011	11.57	2.82	3.28	0.63
2012	13.01	3.18	3.69	0.71
2013	13.71	3.35	3.89	0.74
2014	11.78	2.88	3.34	0.64
Trend 2013–2014	-14%	-14%	-14%	-14%
Trend 1990–2014	-24%	-33%	-24%	-71%
Share in CRF 3 in 1990		28%	28%	14%
Share in CRF 3 in 2014		24%	28%	5%
Share in National Total 1990	0.12%	0.03%	0.03%	0.02%
Share in National Total 2014	0,07%	0,02%	0,02%	0,00%

Greenhouse gas emissions in this sector increased weakly by 2.58% between 1990 and 2014, 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<sup>109</sup>;
- 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<sup>110</sup>
- 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;

<sup>109</sup> 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).

<sup>110</sup> 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.

- Convention on Long-range Transboundary Air Pollution (LRTAP)<sup>111</sup>, extended by eight protocols from which the following have relevance:
  - The 1988 Protocol concerning the Control of Nitrogen Oxides or their Transboundary Fluxes;<sup>112</sup>
  - The 1991 Protocol concerning the Control of Emissions of Volatile Organic Compounds or their Transboundary Fluxes;<sup>113</sup>
  - The 1998 Protocol on Persistent Organic Pollutants (POPs);<sup>114</sup>
  - The 1999 Protocol to Abate Acidification, Eutrophication and Ground-level Ozone; 21 Parties.<sup>115</sup>
- Ordinance for volatile organic compounds (VOC) due to the use of organic solvents in certain activities and installations;<sup>116</sup>
- 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.<sup>117</sup>

#### 4.5.3.1.3 Completeness

Table 4-23 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

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<sup>111</sup> 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)

<sup>112</sup> 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)

<sup>113</sup> 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)

<sup>114</sup> 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)

<sup>115</sup> 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)

<sup>116</sup> *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;*

<sup>117</sup> *Règlement grand-ducal du 12 juillet 1995, relatif aux générateurs d'aérosols.*

emission estimates of all subcategories. A “✓” indicates that emissions from this sub-category have been estimated.

**Table 4-23 - Overview of subcategories of IPCC Category 3 - Solvents and Other Product Use: correlation with SNAP codes and status of estimation.**

IPCC Category		SNAP	CO <sub>2</sub>	N <sub>2</sub> O
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<sub>2</sub> Emissions from Solvent and Other Product Use

##### 4.5.3.1.4.1 Methodology Overview

CO<sub>2</sub> 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, 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<sup>118</sup> (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<sub>2</sub> 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.

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Figure 4-8 - Top-down-Approach compared to Bottom-up-Approach.

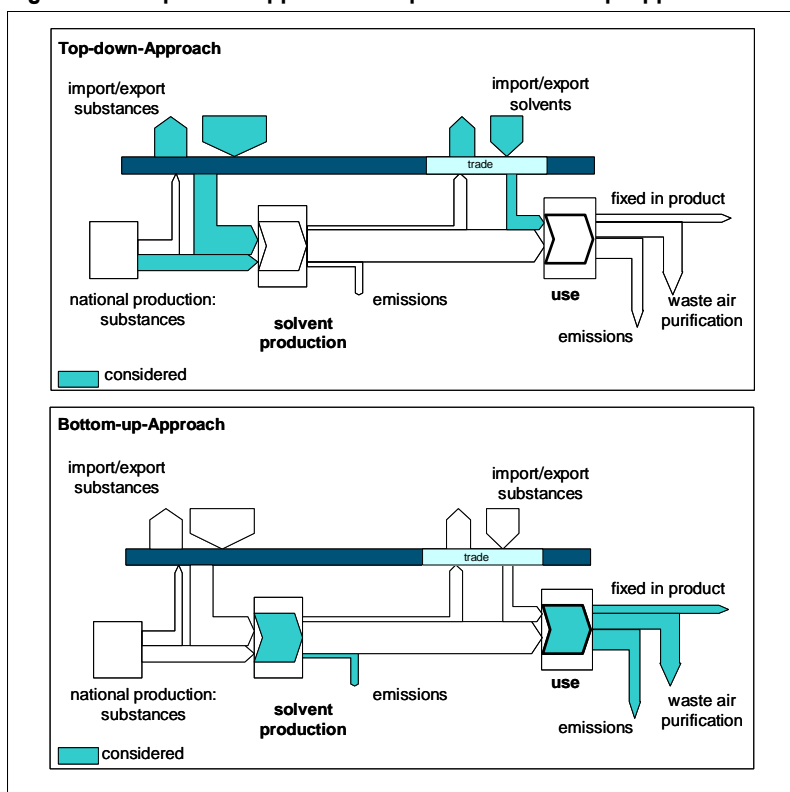
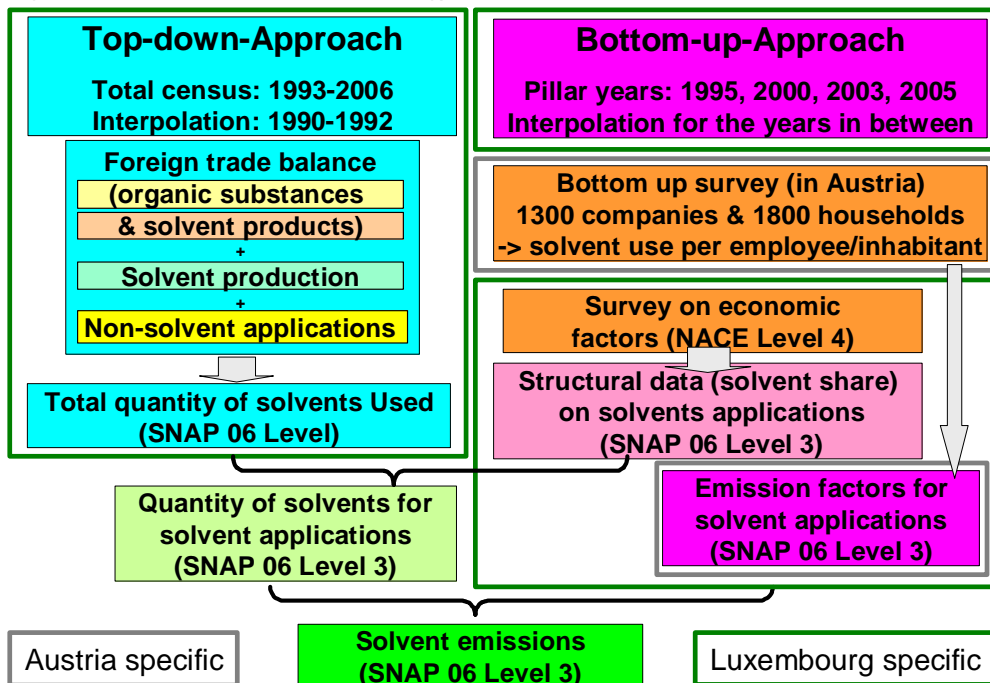


Figure 4-9 - Overview of the methodology for solvent emissions.



Top-down					Bottom-up							Combination Top-down to Bottom-up										
CRF Sector 3					CRF Sector 3A-3D	SNAP Level 3			Solvent Share			Solvent Emission Factor			Solvent Activity			Solvent Emissions				
								CRF 3	CRF 3A-D	SNAP Lev 3	CRF 3	CRF 3A-D	SNAP Lev 3	CRF 3	CRF 3A-D	SNAP Lev 3	CRF 3	CRF 3A-D	SNAP Lev 3	CRF 3	CRF 3A-D	SNAP Lev 3
Imp/Exp Solvent products	2			Solvent Activity	7	3 A, Paint application	060101	Manufacture of automobiles	26%		67%	1.9	0.0	0.0	1.3	0.0	0.0					
							060102	Car repairing					0.3%			64%		0.0				
							060103	Construction and buildings					1.0%			86%		0.1				
							060104	Domestic use					6.6%			89%		0.5				
							060105	Coil coating					1.3%			89%		0.1				
							060106	Wood coating					2.4%			52%		0.2				
							060107	Other industrial paint application					2.3%			90%		0.2				
Inland Solvent production	10			Solvent Activity	7	3 B, Degreasing and Dry Cleaning	060108	Metal degreasing	31%		51%	2.3	0.9	0.0	1.2	0.0	0.0					
							060201	Dry cleaning					11.9%			29%		1.0				
							060202	Electronic components manufact.					13.6%			84%		0.0				
							060203	Other industrial cleaning					0.3%			82%		0.0				
							060204	Rubber processing					0.0%			68%		1.2				
							060305	Pharmaceutical products manufact.					6.3%			93%		0.5				
							060306	Paints manufacturing					0.7%			26%		0.1				
Imp/Exp Organic Substances	14			Solvent Activity	7	3 C, Chemical Products, Manufacture and Processing	060307	Inks manufacturing	100%		83%	0.7	0.0	5.0	0.6	0.0	0.0					
							060308	Glues manufacturing					0.5%			100%		0.0				
							060309	Asphalt blowing					0.7%			100%		0.0				
							060310	Adhesive, films & photographs					0.0%			100%		0.0				
							060311	Textile finishing					0.0%			94%		0.0				
							060312	Other manufacturing					0.0%			90%		0.0				
							060314	Printing industry					0.9%			100%		0.1				
Non-solvent applications	-19			Solvent Activity	7	3 D, Other	060403	Fat and oil extraction	34%		79%	2.5	0.7	2.0	1.0	0.0	0.0					
							060404	Application of glues and adhesives					0.3%			20%		0.0				
							060405	Preservation of wood					0.0%			63%		0.0				
							060406	Treatment & conservation of vehicles					0.1%			99%		0.0				
							060407	Domestic solvent use (other)					0.3%			85%		0.0				
							060408	Domestic use of pharmac. products					17.3%			84%		1.3				
							060411	Other (preservation of seeds...)					4.0%			94%		0.3				
		2.1%	78%	0.2																		

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.

The top-down approach is based on:

- 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 4-24).

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 <sup>119</sup>.

**Table 4-24 - 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 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 4-25, Table 4-26 and Table 4-27). 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

<sup>119</sup> <http://epp.eurostat.ec.europa.eu>

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 4-25 - 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 4-26 - 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%

SNAP category	description	year	Distribution of used paints		Part of waste gas treatment	
			Solvent based paints	Water based paints	application	Purification
		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 4-27 - 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%

SNAP	Description	Changes in the number of employees compared to the year 2000				
		1990	1995	2000	2003	2005
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)					
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 4-28). The differences between the quantities of solvents from the top down approach and bottom up approach respectively are lower than 10%. Table 4-29 shows the range of the differences in the considered pillar years broken down to the 15 substance categories.

**Table 4-28 - 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 4-29, Table 4-30 and Figure 4-11) present activity data and NMVOC emissions.

**Table 4-29 - Activity data of category 2D3-Solvent and other product use [Mg] 1990-2014**

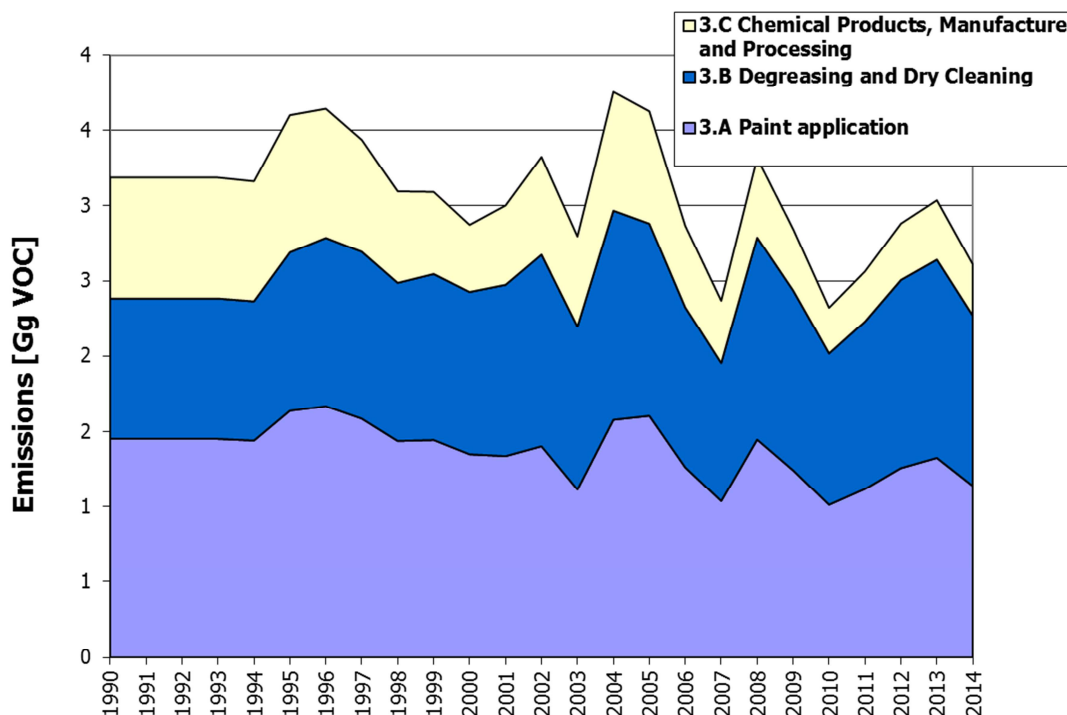
Solvents (Gg)										
	2D3	2D3a	2D3b	2D3c	2D3d	2D3e	2D3f	2D3g	2D3h	2D3i
	TOTAL	Dometics solvent use including fungicides	Road paving with asphalt	Asphalt roofing	Coating applications	Degreasing	Dry cleaning	Chemical products	Printing	Other solvent use (please specify in the IR)
1990	7.124	1.309	IE	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



Table 4-30 - Implied NMVOC emission factors for 2D3-Solvent Use 1990–2014

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

Figure 4-11 - NMVOC emissions and trend from 1990–2014 by subcategories of category 2D3 - Solvent and Other Product Use



#### 4.5.3.1.4.5 Calculation of CO<sub>2</sub> 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 4-31) on the basis of the carbon content and the stoichiometrically formed CO<sub>2</sub>.

Table 4-31 - Substance specific carbon dioxide emission factors

Substances	CO <sub>2</sub> factor [kg CO <sub>2</sub> /kg substance]	Substances	CO <sub>2</sub> factor [kg CO <sub>2</sub> /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
Cyclic Hydrocarbons	3.14	Solvent naphtha	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 4-33, the implied CO<sub>2</sub> Emission factors of Austria, which were also

used for Luxembourg, as well as in Table 4-32, the carbon dioxide emissions of Category 3-Solvent and Other Product Use for the years 1990 to 2014 are shown.

**Table 4-32 - CO<sub>2</sub> emission of Category 2D3-Solvent and Other Product Use 1990–2014.**

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

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
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

SNAP	0602	060201	060202	060203	060204
Unit	Gg				
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

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

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

SNAP	0604	060403	060404	060405	060406	060407	060408	060411	060412
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

**Table 4-33 - Implied CO<sub>2</sub> Emission factors for Category 2D3-Solvent and Other Product Use 1990–2014.**

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
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

SNAP	060101	060102	060103	060104	060105	060107	060108
Unit	kg/Mg Solvent						
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

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

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
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

SNAP	060305	060306	060307	060308	060309	060310	060311	060312	060314
Unit	kg/Mg Solvent								
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

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
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

#### 4.5.3.1.5 Uncertainties and time-series consistency

The error values which are assumed on the various calculations are as given:

- 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 (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?

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 4-34 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<sup>120</sup>: country-specific data were used to update the pillar years 2005 and 2010 in bottom-up approach. For the quantitative aspect of these recalculations, please refer to Chapter 10.

**Table 4-34 – Recalculations done since submission 2015v1**

GHG source & sink category	Revisions 2015v1 → 2016v1	Type of revision
2.D.3.1	update of data of the top-down approach: production statistics, import and export statistics data of 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”.	updated 2.D.3.1

#### 4.5.3.1.8 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 4-35 will be explored.

**Table 4-35 – Planned improvements for Sector 3 – Solvent and Other Product Use**

GHG source & sink category	Planned improvement

<sup>120</sup> ARR 2010, § 52 Solvent and other product use - CO<sub>2</sub>: Luxembourg bases its CO<sub>2</sub> emission estimates for this category on AD from Luxembourg using an implied CO<sub>2</sub> 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.

2.D.3.1	Investigate the possibility of acquiring more country-specific data in order to establish the emission levels from solvent and other product use. <sup>121</sup> Nevertheless, the IEF for CO <sub>2</sub> emission from Austria seemed to be more accurate and applicable than the default fossil carbon content fraction provided by the 2006 IPCC GL <sup>122</sup> because the IEF CO <sub>2</sub> is based on substance specific carbon dioxide factors for 15 substances. The amount of these substances used in Luxembourg (production/import/export) is taken into account in emission estimation.
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#### 4.5.3.2 Urea-based catalysts (2.D.3.2)

##### 4.5.3.2.1 Source category description

In 2014, CO<sub>2</sub> emissions resulting from the use of urea-based catalysts in SCR-equipped vehicles was responsible for 1.46% of GHG emissions from industrial processes and product use and for 0.09% of the total GHG emissions in CO<sub>2</sub>e (excluding LULUCF). Compared to 2013, emissions increased by 5.2% to reach 9.42 Gg CO<sub>2</sub> in 2014. An overview of the related CO<sub>2</sub> emissions is provided in Table 4-36 - CO<sub>2</sub> emissions trend, activity data and IEFs for IPCC sub-category 2.D.3.2 – Urea-based catalysts: 1990-2014..

2.D.3.2 – Urea-based catalysts is not a key source with regard to CO<sub>2</sub> emissions.

<sup>121</sup> ARR 2010, § 52 Solvent and other product use - CO<sub>2</sub>: Luxembourg bases its CO<sub>2</sub> emission estimates for this category on AD from Luxembourg using an implied CO<sub>2</sub> 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.

<sup>122</sup> "The default fossil carbon content fraction of NMVOC is 60 percent by mass, based on limited published national analyses of the speciation profile (U.S. EPA, 2002; Austria, 2004; Hungary, 2004; Klein Goldewijk et al., 2005). It may vary between 50 and 70 percent carbon by mass, so having an uncertainty of about  $\pm 10$  percent. Country-specific fractions should have a lower uncertainty, e.g.,  $\pm 5$  percent." 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3, Chapter 5: Industrial Processes and Product Use, page 5.17, and 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 1, Chapter 7: Precursors and Indirect Emissions, page 7.6.

Table 4-36 - CO<sub>2</sub> emissions trend, activity data and IEFs for IPCC sub-category 2.D.3.2 – Urea-based catalysts: 1990-2014.

<i>2D3 - Urea-based catalysts</i>			
Year	activity data (t)	CO <sub>2</sub> emissions (Gg)	implied emission factor (t CO <sub>2</sub> /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	1 102	0.26	0.238
2006	3 735	0.89	0.238
2007	9 749	2.32	0.238
2008	18 117	4.32	0.238
2009	21 500	5.12	0.238
2010	28 987	6.91	0.238
2011	35 285	8.41	0.238
2012	35 881	8.55	0.238
2013	37 603	8.96	0.238
2014	39 542	9.42	0.238
<i>Trend</i> 1990-2014	NA	NA	
<i>Trend</i> 2013-2014	5.16%	5.16%	

Source: Environment Agency

#### 4.5.3.2.2 Methodological issues

##### 4.5.3.2.2.1 Activity data

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).

#### 4.5.3.2.2.2 Methodology

CO<sub>2</sub> 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<sup>123</sup>. The calculation is based on the assumption that one mole of urea generates one mole of CO<sub>2</sub> and converts 0.9 mole of NO<sub>x</sub> as illustrated by Equation 4-1.

**Equation 4-1: Formula used by the NEMO model to determine CO<sub>2</sub> emissions from the use of AdBlue® in SCR-equipped vehicles.**

$$\text{CO}_2 [g] = \frac{(\text{NO}_{x,\text{EO}} - \text{NO}_{x,\text{TP}})[g]}{\underbrace{46 \left[ \frac{g}{\text{mol}} \right]}_{\text{molar mass NO}_2}} \cdot \left( \frac{1}{1 - s_{\text{NH}_3,\text{loss}}} \right) \cdot \underbrace{\left( \frac{1}{2} \right)}_{\text{CO}_2 / \text{NH}_3 \text{ mole ratio}} \cdot \underbrace{44 \left[ \frac{g}{\text{mol}} \right]}_{\text{molar mass CO}_2}$$

With:

NO<sub>x,EO</sub>: NO<sub>x</sub> emissions (in NO<sub>2</sub> mass equivalent) at engine out

NO<sub>x,TP</sub>: NO<sub>x</sub> emissions (in NO<sub>2</sub> mass equivalent) at tailpipe

s<sub>NH<sub>3</sub>,loss</sub>: share of NH<sub>3</sub> losses caused by NH<sub>3</sub> slip through SCR catalyst without NO<sub>x</sub> conversion and by NH<sub>3</sub> not generated from urea. The value used for s<sub>NH<sub>3</sub>,loss</sub> is 10% (expert judgment by IVT Graz).

#### 4.5.3.2.2.3 Emission factors

The CO<sub>2</sub> 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<sup>124</sup>.

#### 4.5.3.2.3 Uncertainties and time-series consistency

The uncertainty for activity data is estimated to be +/-20% (expert judgement by TU Graz, 2015). The timeseries is considered to be consistent.

#### 4.5.3.2.4 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.

<sup>123</sup> 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

<sup>124</sup> 2006 IPCC Guidelines, Volume 2, Chapter 3, p. 3.12

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

No recalculations were done in sub-category 2.D.3.2.

4.5.3.2.6 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)**

This source category does not exist in Luxembourg.

## **4.7 Product uses as substitutes for ODS (2.F)**

In relation with the consumption of halocarbons and SF<sub>6</sub>, 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 2014, this category represented 10.98% of the GHG emissions in CO<sub>2</sub>e from industrial processes and 0.57% of the total GHG emissions in CO<sub>2</sub>e (excluding LULUCF). This percentage was only 0.10% in 1995. As shown in Figure 4-12, the related emissions experienced a major increase between 1995 and 2014 (+280%). Compared to 2013, emissions increased by 15.06% to attain the level of 68.29 Gg CO<sub>2</sub> in 2014.

F-gas emission estimates are presented in Table 4-37.

Figure 4-12 – GHG emission trends for CRF Sector 2F – HFCs: 1990-2014

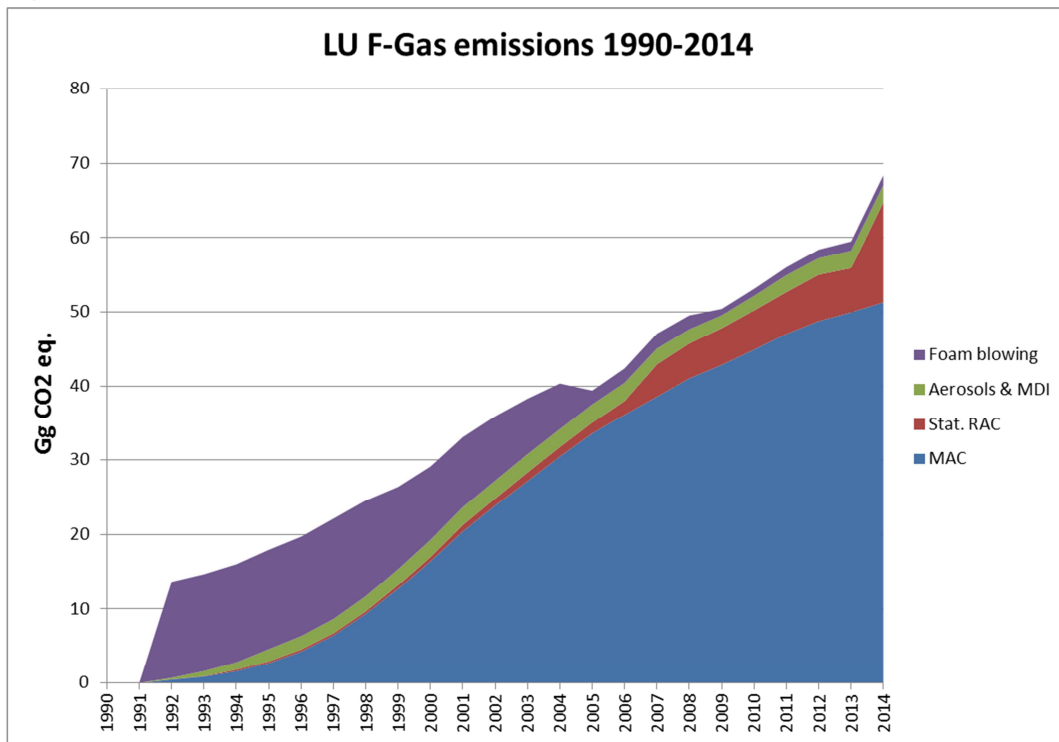




Table 4-37 – Estimated emissions of HFCs: 1990-2014

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)	2F4 - Aerosols/ Metered Dose Inhalers (HFC)
	Gg CO <sub>2</sub> 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	17.97	2.95	0.24	2.70	13.38	1.65
1996	19.71	4.55	0.29	4.26	13.36	1.80
1997	22.13	6.73	0.32	6.41	13.47	1.92
1998	24.54	9.69	0.35	9.34	12.81	2.04
1999	26.38	13.23	0.51	12.72	10.99	2.15
2000	29.13	17.01	0.57	16.44	9.85	2.27
2001	33.10	21.28	0.89	20.40	9.45	2.37
2002	35.92	24.81	0.96	23.85	8.70	2.41
2003	38.28	28.33	1.20	27.14	7.49	2.46
2004	40.34	31.77	1.29	30.48	6.16	2.40
2005	39.38	35.06	1.46	33.60	1.87	2.46
2006	42.38	37.98	1.86	36.12	1.94	2.45
2007	47.08	42.94	4.38	38.55	2.02	2.12
2008	49.55	45.75	4.71	41.03	1.88	1.93
2009	50.42	47.83	4.99	42.84	0.86	1.73
2010	53.13	50.22	5.32	44.90	0.95	1.95
2011	56.03	52.70	5.67	47.04	1.06	2.27
2012	58.42	55.05	6.27	48.78	1.15	2.22
2013	59.35	55.93	5.98	49.95	1.25	2.17
2014	68.29	64.75	13.43	51.32	1.29	2.25
<b>Trend</b>						
<b>1995-2014</b>	280%	2098%	5459%	1798%	-90%	37%
<b>Trend</b>						
<b>2013-2014</b>	15.06%	15.75%	124.49%	2.73%	3.60%	3.84%

Source: Environment Agency

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.

#### 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<sub>6</sub> 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.

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

No revisions and recalculations have been done since the last submission.

#### **4.7.1.4 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 4-38).

**Table 4-38 – Planned improvements for IPCC Category 2F – Product uses as substitutes for ODS**

<b>GHG source &amp; sink category</b>	<b>Planned improvement</b>	<b>Recommendation</b>
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 2014, the category 2.G represented 2.08% of the GHG emissions in CO<sub>2</sub>e from industrial processes and 0.09% of the total GHG emissions in CO<sub>2</sub>e (excluding LULUCF). This percentage was 0.10% in 1995. As shown in Figure 4-13, F-gas emissions experienced an increase of 49% between 1995 and 2014. Compared to 2013, emissions decreased by 6.82% to attain the level of 12.95 Gg CO<sub>2</sub> in 2014.

F-gas emission estimates are presented in Figure 4-13 and Table 4-38.

**Figure 4-13 – F-gas emission estimates for category 2.G: 1990-2014**

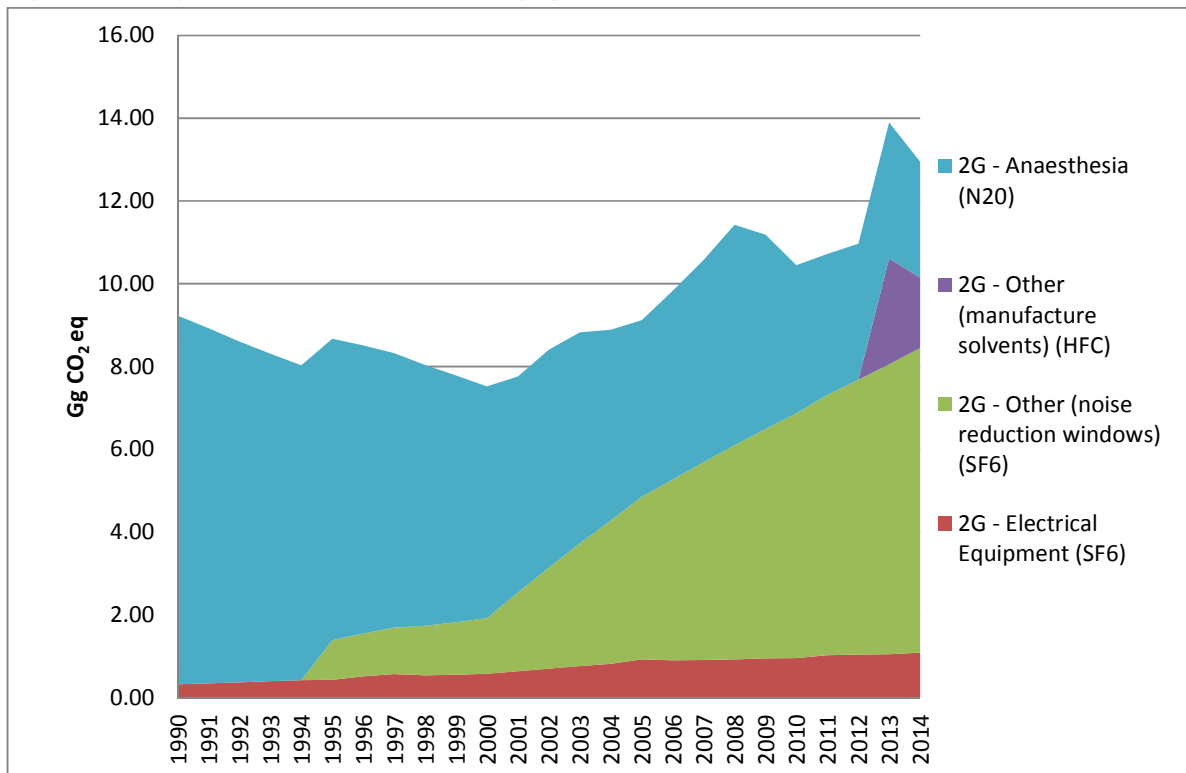


Table 4-39 – F-gas emission estimates for category 2.G: 1990-2014

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 <sub>2</sub> O)
	Gg CO <sub>2</sub> e				
1990	9.23	0.33	0.00	0.00	8.91
1991	8.93	0.35	0.00	0.00	8.58
1992	8.60	0.37	0.00	0.00	8.23
1993	8.31	0.40	0.00	0.00	7.91
1994	8.03	0.43	0.00	0.00	7.60
1995	8.67	0.43	0.96	0.00	7.28
1996	8.51	0.52	1.04	0.00	6.95
1997	8.32	0.57	1.12	0.00	6.63
1998	8.04	0.54	1.20	0.00	6.30
1999	7.78	0.56	1.27	0.00	5.95
2000	7.52	0.58	1.35	0.00	5.59
2001	7.76	0.64	1.90	0.00	5.22
2002	8.41	0.70	2.44	0.00	5.26
2003	8.82	0.77	2.96	0.00	5.09
2004	8.89	0.82	3.47	0.00	4.61
2005	9.12	0.93	3.93	0.00	4.27
2006	9.83	0.91	4.36	0.00	4.56
2007	10.58	0.91	4.78	0.00	4.88
2008	11.43	0.93	5.17	0.00	5.33
2009	11.18	0.95	5.54	0.00	4.69
2010	10.45	0.96	5.91	0.00	3.58
2011	10.72	1.03	6.28	0.00	3.41
2012	10.96	1.04	6.64	0.00	3.28
2013	13.90	1.05	7.00	2.56	3.28
2014	12.95	1.09	7.35	1.71	2.80
<b>Trend</b>					
1995-2014	49%	152%	669%	NA	-62%
<b>Trend</b>					
2013-2014	-6.82%	3.72%	5.07%	-33.46%	-14.75%

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

No revisions and recalculations have been done since the last submission.

#### **4.8.1.4 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 (SF<sub>6</sub>) 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 SF<sub>6</sub> 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 SF<sub>6</sub> MV equipment.

Individual charges typically vary between less than 1 kg of SF<sub>6</sub> 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 SF<sub>6</sub>

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 SF<sub>6</sub> and HFCs from other product use (2.G.2)**

##### Noise reduction windows

A life-cycle approach is applied:

$$Emissions = EF \bullet AR + D$$

The activity rate (AR) is the calculated SF<sub>6</sub> 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<sub>6</sub> is assumed to be 1% (EF=1%) and the lifespan 25 years. Disposal emissions (D) of the remaining SF<sub>6</sub> stock occur after a lifetime of 25 years.

##### Manufacture solvents

Since 2013, DuPont De Nemours (Luxembourg) s.à.r.l. exploits its Tyvek Line 3 in which HFC-4310mee is used as a manufacture solvent (spinning agent). The annual report indicates the stock of HFC-4310mee at the end of the year 2014 as well as the amount of HFC-4310mee emitted during that year.



#### 4.8.4 N<sub>2</sub>O from product uses (2.G.3)

##### 4.8.4.1 Medical applications (2.G.3.a)

N<sub>2</sub>O emissions from Anaesthesia

In 2014, 0.0002% of total GHG emissions (excluding LULUCF) in Luxembourg originated from 2G3 - N<sub>2</sub>O emissions from anaesthesia, compared to 0.0008% in 1990. Compared to 2013, N<sub>2</sub>O emissions from anaesthesia decreased by 14.75% and by 62% compared to 1990.

It was assumed that all the N<sub>2</sub>O used for anaesthesia is completely released to the atmosphere. Emissions are shown in Table 4-40 and Figure 4-14.

For the period 1990-2002, no data from the hospitals on the consumption of N<sub>2</sub>O could be obtained. Hence, N<sub>2</sub>O emissions from anaesthesia usage were estimated by combining reported emissions in Germany with the relative population in Luxembourg. From 2003 to 2014, the use of N<sub>2</sub>O 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<sub>2</sub>O for anaesthesia in all hospitals of Luxembourg.

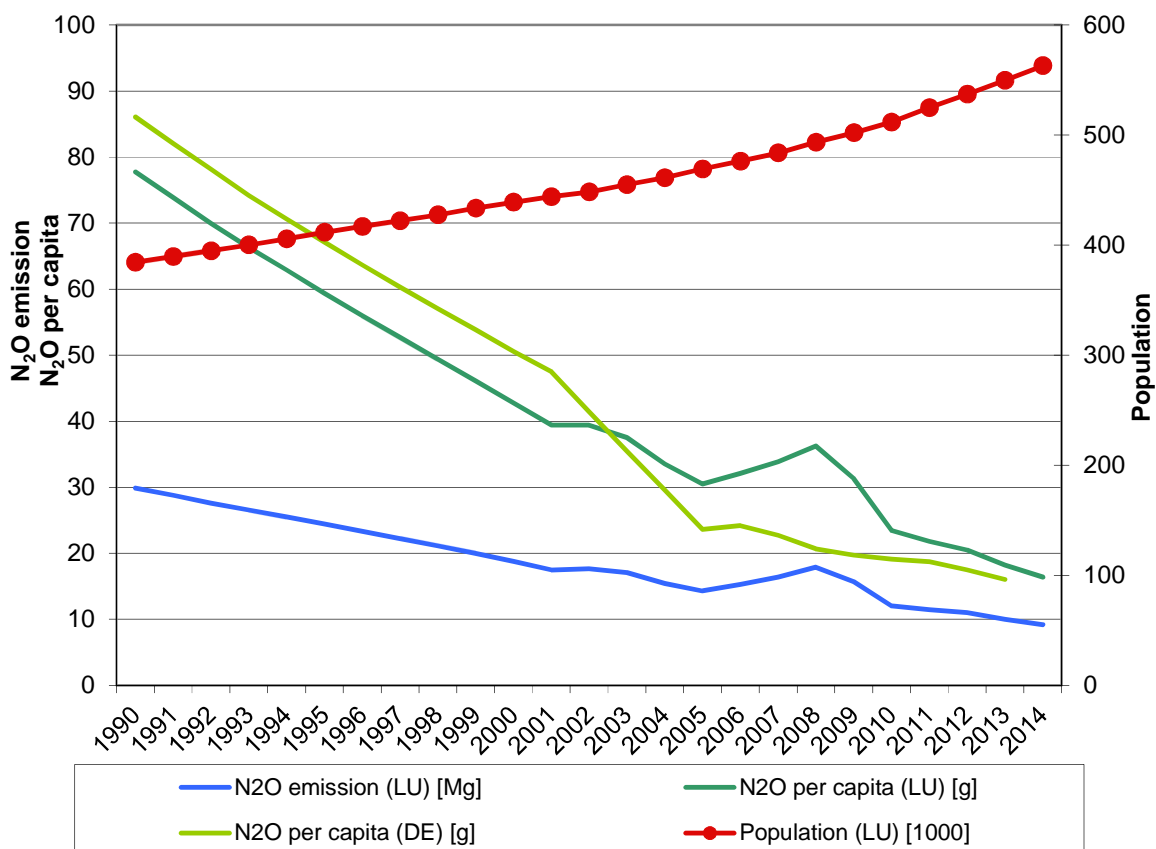
Although two different methods for the estimation of N<sub>2</sub>O from anaesthesia are used over the time period (1990-2002 and 2003-2014), it is estimated that the time-series consistency is ensured. Indeed, when comparing the 2002 and 2003 values of emissions per capita of Germany with Luxembourg's value, these are relatively similar (Table 4-40). 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 4-40 - 3D1 - Use of N<sub>2</sub>O for Anaesthesia: 1990–2014.**

	N <sub>2</sub> O emission (LU) [Mg]	Population (LU) [1000]	N <sub>2</sub> O per capita (LU) [g]	N <sub>2</sub> O 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	60,31
1998	21.13	427.4	49.43	57,07
1999	19.98	433.6	46.08	53,86

	N <sub>2</sub> O emission (LU) [Mg]	Population (LU) [1000]	N <sub>2</sub> O per capita (LU) [g]	N <sub>2</sub> O per capita (DE) [g]
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	18,71
2012	11.01	537.0	20.51	17,50
2013	10.02	549.7	18.22	16,05
2014	9.22	563.0	16.38	/

Figure 4-14 – N<sub>2</sub>O emissions and N<sub>2</sub>O consumption for anaesthesia per capita and trend: 1990–2014



#### 4.8.4.1.1 Uncertainties and time-series consistency

Direct use of N<sub>2</sub>O 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<sub>2</sub>O is used. In contrast to Ramirez, it is assumed that virtually all of the N<sub>2</sub>O actually used is also fully released, thus no additional uncertainty is applied.

**Table 4-41 - Uncertainties for category 3D1 - N<sub>2</sub>O emissions from anaesthesia.**

IPCC Source category	Gas	AD	EF	Combined
			Uncertainty [%]	
3D1 - N <sub>2</sub> O emissions from anaesthesia	N <sub>2</sub> O	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

No revisions and recalculations have been done since the last submission.

#### 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.4)**

This source category does not exist in Luxembourg.

#### **4.9 Other (2.H)**

This source category does not exist in Luxembourg.

## **5 Agriculture (CRF Sector 3)**

### **5.1 Sector Overview**

Chapter 5 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 2014.

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 2014 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 5-1, emissions of GHG related to agricultural activities have decreased by about 6.63% (-1.88% for methane and -16.22% for nitrous oxide). IPCC Category 3A – Enteric Fermentation saw its emissions falling by 4.18%, whereas for IPCC category 3D – Agricultural Soils, the decrease reaches 14.46%. For manure management (IPCC Category 3B), emissions rose by 7.81% between 1990 and 2014, though opposite variations are observed for the two GHG emitted by this activity: methane increased by 17.32% and nitrous oxide declined by 10.96%.

Table 5-1 provides a quick overview on agriculture related emission trends between 1990 and 2014. 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: 1990-2014**

	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
Trend	-4,18%		-4,18%		7,81%		17,32%	-10,96%	-14,46%	885,07%		-16,71%	-6,63%	885,07%	-1,88%	-16,22%

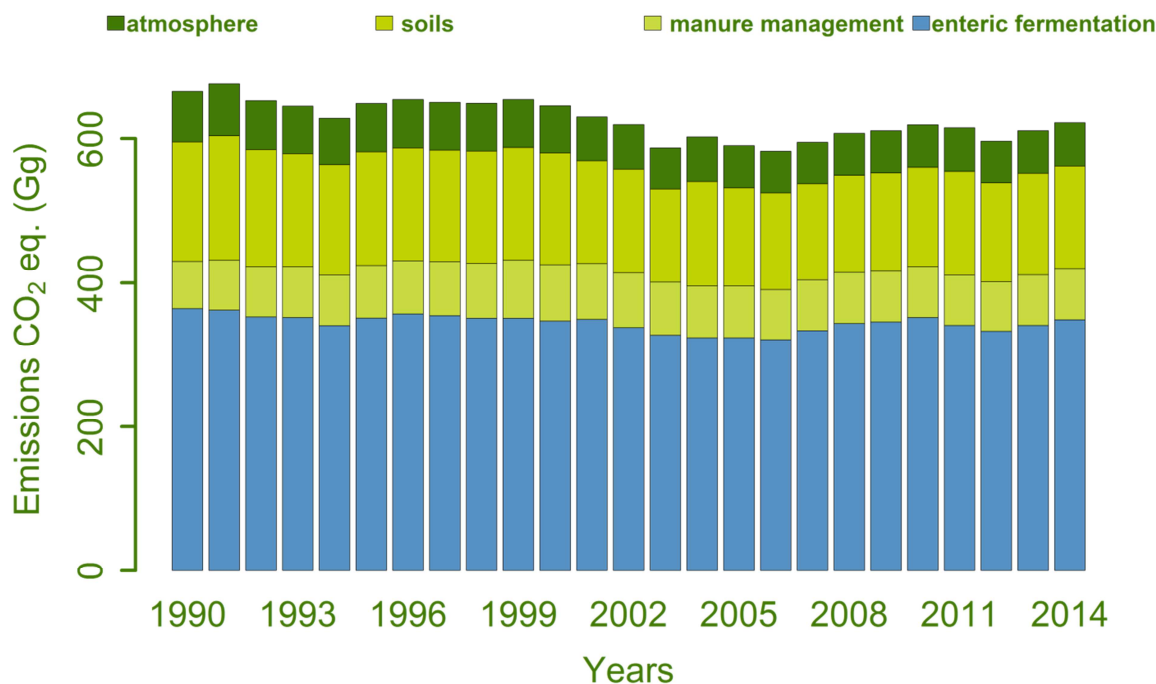
Notes:

a) CH<sub>4</sub> emissions are converted in CO<sub>2</sub> eq. by multiplying the emissions by 21, i.e. the global warming potential (GWP) value for methane.

b) N<sub>2</sub>O emissions are converted in CO<sub>2</sub> eq. by multiplying the emissions by 310, i.e. the global warming potential (GWP) value for nitrous oxide

As depicted in Figure 5-1, for both the years 1990 and 2014, 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 (CO<sub>2</sub> eq.): 1990 - 2014**

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<sub>4</sub> and N<sub>2</sub>O 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 5-2 presents the key source categories of IPCC Sector 3 – Agriculture.

**Table 5-2– Key sources of IPCC Sector 3 – Agriculture**

<b>3 - Agriculture</b>						
<b>Key sources</b>						
<b>IPCC Category</b>	<b>Category Name</b>	<b>GHG</b>	<b>LA excl. LULUCF</b>	<b>LA incl. LULUCF</b>	<b>TA excl. LULUCF</b>	<b>TA incl. LULUCF</b>
3A	Enteric Fermentation	CH <sub>4</sub>	90-14	90-94, 96, 98-01, 03-14		
3B	Manure Management	CH <sub>4</sub>	97-03	97-03		
3D1	Direct N <sub>2</sub> O Emissions from Managed Soils	N <sub>2</sub> O	90-14	90-14		

Source: Environment Agency

Notes:

LA = Level Assessment (Tier 1) including respectively excluding LULUCF

TA = Trend Assessment 2014 (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<sub>2</sub> 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<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O**

GHG source & sink category	Description	Status		
		CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
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		

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.

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 2014, this source category was responsible for 87.21% of agricultural methane emissions and for 72.9% of the total methane emissions estimated for Luxembourg. It represented 56.18% of the total GHG emissions from the agriculture sector and 3.9% of the total GHG emissions in CO<sub>2</sub>e (excluding LULUCF).

### **5.2.1 Key source**

With 3.9% of the total GHG emissions in CO<sub>2</sub> eq., excluding LULUCF in 2014 (4.0% of the total GHG emissions in CO<sub>2</sub> eq., including LULUCF), enteric fermentation (IPCC Sub-category 3A) has been a key source without interruption since 1990 if LULUCF is excluded. If LULUCF is included in the key source analysis, sub-category 3A has been a key source for all years since 1990 except for 1995, 1997 and 2002.

**Table 5-4 – Domestic livestock population and trends: 1990-2014**

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
<b>Trend 90 - 14</b>	-11 %	-13 %	21 %	-35 %	-21 %	18 %	-42 %	25 %	20 %	754 %	174 %	-55 %	190 %	-63 %		-78 %	-4 %

Sources: SER – agricultural census.

Notes:

a) mules & asses population are reported together with horses' population.

**Table 5-5 – CH<sub>4</sub> emission trends for IPCC Category 3A – Enteric Fermentation: 1990-2014 (Gg)**

years	calves	young cattle	Bulls 1-2	bulls >2	dairy cows	suckler cows	pigs reprod	fattening pigs	sheep	goats	horses	chickens	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	NA	NA	NA	NA	NA	0,005	16,636
<b>Trend 90 - 14</b>	-10,5%	-12,9%	9,5%	-35,3%	-9,7%	18,1%	-42,4%	24,6%	19,8%	754,2%	174,3%						-4,2%	-4,2%

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 1990-2014, 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 categories, 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<sub>2</sub> equivalent from enteric fermentation by the livestock population.

On the whole, methane emissions from enteric fermentation decreased by around 4.18% over the period 1990-2014. This was mainly the result from declining emissions generated by dairy cows, namely -9.7%. Increasing emissions were recorded for the other livestock categories with +174.3% for horses, +754.2% for goats and +24.6% 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 21% between 1990 and 2014, related methane emissions only declined by 9.7%. 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.

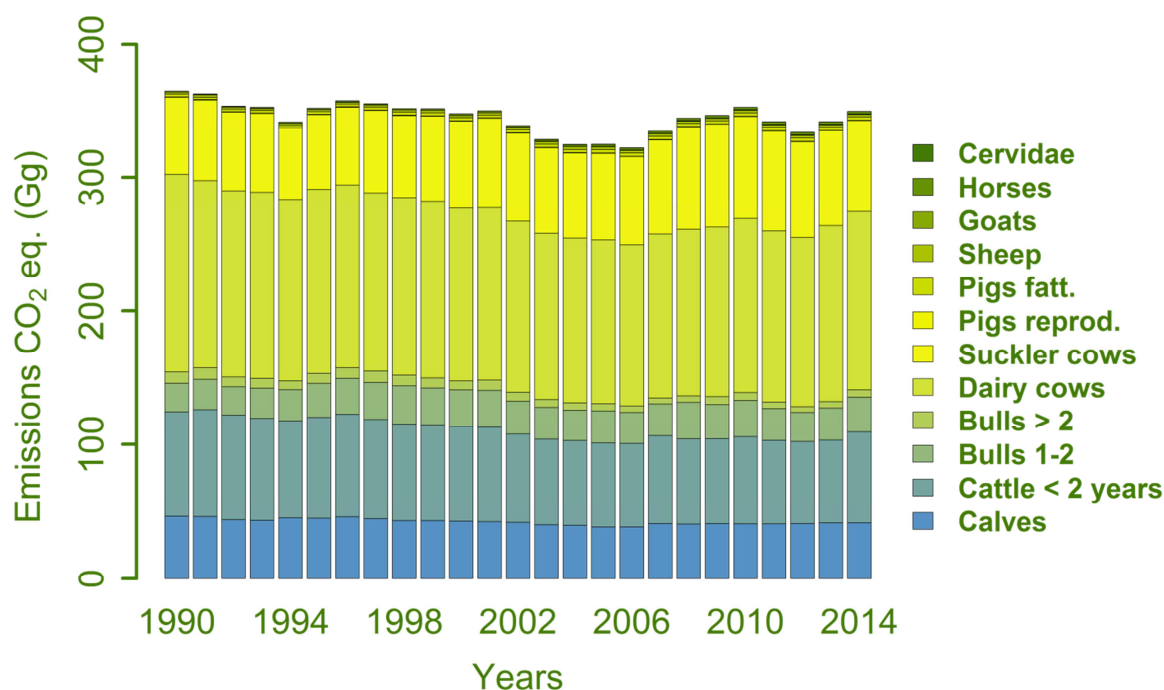


Figure 5-2 – Enteric fermentation per animal category: 1990 - 2014

### 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;
- the 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;
- the 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 1990-2014, the milk yield has increased by 5 %. 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 11%. 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 23.6% increase since 1990 for the IEF expressed in CH<sub>4</sub>/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: 1990-2014**

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	305543	4,09
<b>trend('90-'14)</b>	8%	

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:

$$IEF_i = [GE_i \times Ym_i \times 365.242199] / 55.65$$

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 4A1 – Cattle – Mature Dairy Cattle**

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

AD, parameter, coefficient	Unit	Source(s)	Type of value
Net Energy for Lactation	MJ/day	equation 10.8 + .9 - 2006 IPCC GLs	calculated using daily milk production
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 <sub>4</sub> 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 (updated 130321)	AD (see Table 6-4)
CH <sub>4</sub> emission factors	kg CH <sub>4</sub> / (head * year)	table 10.10 - 2006 IPCC GLs IPCC EFDB	- default for developed countries
CH <sub>4</sub> emissions	Gg CH <sub>4</sub> /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<sub>4</sub> IEFs trends for IPCC Category 4A – Enteric Fermentation: 1990-2014 (kg CH<sub>4</sub> / 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
trend	0%	0%	0%	0%	13%	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

Table 5-12 presents the main revisions and recalculations, as well as their impact, between submissions 2014v1.3 and 2016v1.1 (see also CRF tables 3).

**Table 5-12 – Changes in GHG inventories: submissions 2014v3.1 and 2016v1.1**

year	2014v1.4 (Gg)	2016v1.1 (Gg)	Difference (%)
1990	12,45	17,36	39%
1991	12,41	17,26	39%
1992	11,91	16,82	41%
1993	12,00	16,78	40%
1994	11,90	16,25	37%
1995	12,23	16,75	37%
1996	12,39	17,01	37%
1997	12,14	16,91	39%
1998	12,01	16,74	39%
1999	12,00	16,73	39%
2000	11,84	16,55	40%
2001	11,90	16,65	40%
2002	11,56	16,13	39%
2003	11,22	15,63	39%
2004	11,11	15,45	39%
2005	11,09	15,46	39%
2006	10,98	15,33	40%
2007	11,38	15,93	40%
2008	11,63	16,39	41%
2009	11,73	16,49	41%
2010	11,96	16,78	40%
2011	11,63	16,27	40%
2012	11,39	15,88	39%

Source: SER.

Note: All the years are impacted by the recalculations.

### **5.2.5 Category specific uncertainty**

Animal numbers' uncertainty is estimated between 0.5% (for cattle, which are extremely well covered due to their inclusion in a register) and 2.5% for animals distributed over many small farms (sheep, horses, chicken).

For emission factors, we follow uncertainties developed for Austria. Enteric fermentation CH<sub>4</sub> emissions are uncertain by 20% for cattle, 30% for all other animals.

### **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 2014, this source category was responsible for 11.4% of the total GHG emissions from the agriculture sector and represented 0.9% of the total GHG emissions in CO<sub>2</sub>e (excluding LULUCF). For each of the two gases reported, excluding LULUCF, in 2014:

- CH<sub>4</sub> represented 12.7% of agricultural methane emissions and 10.7% of the total methane emissions estimated for Luxembourg;
- N<sub>2</sub>O represented 9% of agricultural nitrous oxide emissions and 11.6% of the total nitrous oxide emissions estimated for Luxembourg.

#### **5.3.1 Key source**

With 0.89% of the total GHG emissions in CO<sub>2</sub>e, excluding LULUCF in 2014 (0.93% of the total GHG emissions in CO<sub>2</sub>e, including LULUCF), methane emissions from manure management (IPCC Sub-category 3B) were a key source from 1997 to 2003.

#### **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 17.3% can be observed for the period 1990-2014. 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 12.6% is observed for the period 1990-2014. 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<sub>2</sub>O.

Combining both gases - CH<sub>4</sub> and N<sub>2</sub>O - manure management related emissions, expressed in CO<sub>2</sub>e, show an increase of 6% - Table 5-16.

**Table 5-13 – CH<sub>4</sub> emission trends for IPCC Category 3B – Manure Management: 1990-2014 (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
trend ('90 - '14)	- 25,5%	19,3%	62,8%	- 13,0%	35,9%	-17,1%	-48,1%	17,7%	15,8%	1394,8%	159,9%	-55,4%	190,2%	-63,4%		-77,6%	-4,3%	17,3%

**Table 5-14 – N<sub>2</sub>O emission trends for IPCC Category 3B – Manure Management: 1990-2014 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
trend ('90 - '13)	-23,3%	-33,9%	12,4%	-74,7%	-17,2%	4,2%	-119,7%	7,8%	16,6%	85,0%	64,1%	-122,6%	68,6%	-167,9%		-305,7%	-4,4%	-12,6%

Source for Table 5-13 and Table 5-14: SER.



Notes for Table 5-13 and Table 5-14: a) mules & asses are recorded together with horses.

b) N<sub>2</sub>O emissions by livestock category exclude emissions from pasture, range & paddock (PRP).

**Table 5-15 – N<sub>2</sub>O emission trends for IPCC Category 3B – Manure Management: 1990-2014 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
trend '90 -'14		13%	-23%			-11%

Source: SER.

Notes:

a) N<sub>2</sub>O emissions from pasture, range & paddock (PRP) are excluded from the total N<sub>2</sub>O emissions in IPCC Category 3B since they have to be accounted for in IPCC Sub-category 3D2 – Emissions from PRP Manure.

**Table 5-16 – CH<sub>4</sub> & N<sub>2</sub>O emission trends for IPCC Category 3B – Manure Management: 1990-2014**

year	CH <sub>4</sub> (Gg)	N <sub>2</sub> O (Gg)	Total (Gg CO <sub>2</sub> -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	2,439	0,064	70,913
trend '90 -'14	17%	-11%	8%

Source: SER.

Notes: a) N<sub>2</sub>O emissions from pasture, range & paddock (PRP) are excluded from the total N<sub>2</sub>O emissions in IPCC Category 3B since they have to be accounted for in IPCC Sub-category 3D2 – Emissions from PRP Manure.

b) CH<sub>4</sub> is in Gg CH<sub>4</sub>, N<sub>2</sub>O emissions are in Gg N<sub>2</sub>O, total is in Gg CO<sub>2</sub> eq.

### 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 5-21 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: 1990-2014 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%

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: 1990-2014 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%

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: 1990-2014 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%

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: 1990-2014 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%

Source: SER & ASTA calculations (not published): prepared on 19 June 2007 and updated by SER in September 2014.

Compared to the previous submission (2014v1.3), AWMS shares for all animal categories have been revised. In 2010, the yearly agricultural census<sup>125</sup> has been completed by a dedicated survey on agricultural production methods (SAPM).<sup>126</sup> Based on the results of the SAPM, the SER produced interpolated AWMS shares for the years 2000 to 2013, 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<sup>3</sup>CH<sub>4</sub>/kg of VS) and the sum of the fractions of animals by AWMS (in %) multiplied by their corresponding methane conversion factor (*MCF* in %):

$$IEF_i = VS_i \times 365.242199 \times Bo_i \times 0.67 \times [\sum_j MCF_j \times AWMS_{ij}]$$

with  $j$  = the various AWMS identified for each livestock category  $i$

$IEF_i$  expressed in kg CH<sub>4</sub>/head/year

the factor 0.67 expressed in kg/m<sup>3</sup>

→ 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.

<sup>125</sup> See [http://www.ser.public.lu/statistik/agrarstrukturen/statec\\_15\\_mai\\_pluriannuel.pdf](http://www.ser.public.lu/statistik/agrarstrukturen/statec_15_mai_pluriannuel.pdf).

<sup>126</sup> 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 <sub>4</sub> Producing Potential	m <sup>3</sup> CH <sub>4</sub> /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 <sub>4</sub> 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 <sub>4</sub> Producing Potential	m <sup>3</sup> CH <sub>4</sub> /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 <sub>4</sub> Conversion Factor	%	Table 10A.4-9 – 2006 IPCC GLs	default for a cool region

#### 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: 1990-2014 (kg CH4 / 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
trend ('90 - '13)	-17%	37%	35%	35%	73%	-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<sub>2</sub>O 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<sub>i</sub>*) per head for each animal category *i*: see Table 5-25.

Most of the *Nex<sub>i</sub>* proposed by SER have been prepared in the framework of an EC Directive on nitrate and good agricultural practice <sup>127</sup> and/or for the OECD Agro-environmental Indicators Database. The *Nex<sub>i</sub>* also apply for the cross compliance measures provided for the single farm payment scheme of the CAP.<sup>128</sup> Since they are not officially published in Luxembourg, *Nex<sub>i</sub>* values should therefore be considered as an expert judgment.

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<sup>127</sup> Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources.

<sup>128</sup> 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

Source: SER, not published.

### 5.3.4.2 Emission factors

Since the Tier 2 method has been applied to estimate manure management N<sub>2</sub>O 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<sub>2</sub>O emissions per selected AWMS**

	AWMS			
	Liquid System	Solid Storage	Pasture	Digester
Default EF (kg N <sub>2</sub> O-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<sub>2</sub>O-N/year. To obtain N<sub>2</sub>O 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:

$$Nex_{ij} = Nex_i \times (\# \text{ of heads})_i \times AWMS_{ij}$$

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<sub>2</sub>O emissions per AWMS are:

$$N_2O_j = [Nex_j \times EF_j] \times (44/28)$$

with  $Nex_j$  = the total nitrogen excretion per AWMS  $j$  in kg N/year

$EF_j$  expressed in kg N<sub>2</sub>O-N/kg N (see Table 6-27)

Nitrous oxide emissions reported under the source category manure management are the sum of the N<sub>2</sub>O <sub>$j$</sub>  **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

Table 5-27 presents the main revisions and recalculations, as well as their impact, between submissions 2014v3.1 and 2016v1.1 (see also CRF tables 8).

**Table 5-27 – Changes in GHG inventories: submissions 2014v3.1 and 2016v1.1**

GHG source & sink category	Revisions 2014v3.1 → 2016v1.1	Type of revision
All years, all categories	Change to 2006 IPCC Methods	Change of Methodology

#### Impacts of the recalculations on the emissions

Year	CH <sub>4</sub> CO <sub>2</sub> eq.			N <sub>2</sub> O CO <sub>2</sub> eq.		
	2014 v 1.4	2015 v 1.1	Difference	2014 v 1.4	2015 v 1.1	Difference
1990	78,64	43,66	-44%	41,38	22,12	-47%
1991	84,99	47,69	-44%	35,63	21,74	-39%
1992	85,68	48,43	-43%	32,49	21,24	-35%
1993	88,53	49,23	-44%	32,05	21,11	-34%
1994	88,48	48,71	-45%	30,72	20,63	-33%
1995	92,89	50,98	-45%	31,69	22,05	-30%
1996	93,41	51,46	-45%	32,11	22,35	-30%
1997	95,88	52,59	-45%	30,31	22,22	-27%
1998	99,14	53,83	-46%	28,73	22,09	-23%
1999	108,56	58,48	-46%	24,25	22,03	-9%
2000	103,80	56,73	-45%	23,70	21,38	-10%
2001	101,72	56,17	-45%	23,71	21,21	-11%
2002	99,23	54,63	-45%	22,56	20,25	-10%
2003	96,59	52,61	-46%	22,95	20,11	-12%
2004	94,31	51,46	-45%	22,83	19,59	-14%
2005	95,07	51,42	-46%	24,56	19,50	-21%
2006	90,74	49,72	-45%	25,84	18,91	-27%
2007	90,71	50,31	-45%	28,23	19,23	-32%
2008	89,60	50,45	-44%	30,50	19,63	-36%
2009	88,21	50,00	-43%	32,47	19,54	-40%
2010	89,60	50,62	-44%	34,54	19,70	-43%
2011	90,23	50,02	-45%	33,25	19,07	-43%
2012	89,47	49,13	-45%	32,32	18,64	-42%

Source: SER.

### **5.3.6 Category specific uncertainty**

The uncertainty associated with activity statistics is generally believed to be quite small. Animal numbers' uncertainty is estimated between 0.5% (for cattle, which are extremely well covered due to their inclusion in a register) and 2.5% for animals distributed over many small farms (sheep, horses, chicken).<sup>129</sup>

For emission factors, we follow uncertainties developed for Austria. Manure application emission factor follow a 70% uncertainty for CH<sub>4</sub> and a range from 50% to 200 % for N<sub>2</sub>O.

### **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.

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).

### **5.3.8 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 2014, this source category was responsible for 90.8% of agricultural nitrous oxide emissions and for 52.2% of the total nitrous oxide emissions estimated for Luxembourg. It represented 32.4% of the total emissions due to agricultural activities and 1.4% of the total GHG emissions in CO<sub>2</sub>e (excluding LULUCF).

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<sup>129</sup> ARR 2012, §67: information on CRF 3B related uncertainties was included in this section. for more details on uncertainties related to CRF 3 in general, please refer to section.



### **5.5.1 Key source**

With 1.4% of the total GHG emissions in CO<sub>2</sub>e, excluding LULUCF in 2014 (1.5% of the total GHG emissions in CO<sub>2</sub>e, including LULUCF), nitrous oxide emissions from agricultural soils (IPCC Category 3D) is a key source, whether LULUCF is included or 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<sub>2</sub>O related emissions declined by almost 17.8%.

CO<sub>2</sub> emissions from soils due to liming and usage of urea and C-fertiliser are provisional as there is no data on dolomite, urea 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<sub>2</sub>O emission trends (Gg) for IPCC Category 3D – Agricultural Soils: 1990-2014**

year	synthetic fertilizer	manure	sewage sludge	compost	grazing	crop residues	mineralization	Organic soils	other	atmospheric deposition	nitrogen leaching	total	method
1990	0,309	0,088	0,006	0,000	0,064	0,000	NO	NO	NO	0,063	0,105	0,635	T1
1991	0,334	0,087	0,006	0,000	0,064	0,000	NO	NO	NO	0,065	0,110	0,666	T1
1992	0,305	0,084	0,006	0,000	0,063	0,000	NO	NO	NO	0,061	0,103	0,622	T1
1993	0,289	0,084	0,006	0,000	0,062	0,000	NO	NO	NO	0,059	0,099	0,600	T1
1994	0,284	0,082	0,007	0,000	0,060	0,000	NO	NO	NO	0,058	0,097	0,588	T1
1995	0,285	0,087	0,006	0,000	0,063	0,000	NO	NO	NO	0,060	0,099	0,600	T1
1996	0,281	0,088	0,006	0,000	0,064	0,000	NO	NO	NO	0,060	0,099	0,597	T1
1997	0,275	0,088	0,006	0,000	0,063	0,000	NO	NO	NO	0,059	0,097	0,588	T1
1998	0,279	0,087	0,006	0,000	0,062	0,000	NO	NO	NO	0,059	0,098	0,591	T1
1999	0,284	0,086	0,006	0,000	0,063	0,000	NO	NO	NO	0,059	0,099	0,597	T1
2000	0,280	0,085	0,005	0,000	0,062	0,000	NO	NO	NO	0,059	0,097	0,588	T1
2001	0,239	0,086	0,005	0,000	0,062	0,000	NO	NO	NO	0,055	0,088	0,535	T1
2002	0,249	0,083	0,005	0,000	0,061	0,000	NO	NO	NO	0,055	0,090	0,543	T1
2003	0,203	0,084	0,004	0,000	0,061	0,000	NO	NO	NO	0,050	0,079	0,481	T1
2004	0,257	0,083	0,004	0,000	0,060	0,000	NO	NO	NO	0,055	0,091	0,550	T1
2005	0,224	0,084	0,004	0,000	0,060	0,000	NO	NO	NO	0,052	0,084	0,508	T1
2006	0,221	0,083	0,005	0,000	0,060	0,000	NO	NO	NO	0,052	0,083	0,504	T1
2007	0,209	0,085	0,005	0,000	0,062	0,000	NO	NO	NO	0,052	0,082	0,494	T1
2008	0,209	0,088	0,005	0,000	0,063	0,000	NO	NO	NO	0,052	0,082	0,500	T1
2009	0,210	0,089	0,004	0,000	0,064	0,000	NO	NO	NO	0,052	0,083	0,503	T1
2010	0,210	0,091	0,003	0,000	0,065	0,000	NO	NO	NO	0,053	0,083	0,506	T1
2011	0,234	0,089	0,004	0,000	0,064	0,000	NO	NO	NO	0,055	0,088	0,534	T1
2012	0,215	0,087	0,005	0,000	0,062	0,000	NO	NO	NO	0,052	0,083	0,505	T1
2013	0,219	0,09	0,004	0,000	0,063	0,000	NO	NO	NO	0,053	0,085	0,514	T1
2014	0,219	0,091	0,004	0,000	0,064	0,000	NO	NO	NO	0,054	0,085	0,518	T1
trend ('90 - '14)	-29%	4%	-30%		0%	103%				-14%	-19%	-18%	

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<sub>2</sub>O emissions for IPCC Category 3D – Agricultural Soils**

Fraction	Description	Unit	Value	Source
Frac <sub>BURN</sub>	Fraction of crop residue burned	kg N/kg crop-N	NO	
Frac <sub>FUEL</sub>	Fraction of livestock N excretion in excrements burned for fuel	kg N/kg N excreted	NO	
Frac <sub>GASF</sub>	Fraction of synthetic fertilizer N applied to soils that volatilizes as NH <sub>3</sub> and NO <sub>x</sub>	kg NH <sub>3</sub> -N+NO <sub>x</sub> -N/kg synthetic fertilizer N applied	0.1	table 11.3– 2006 IPCC Guidelines
Frac <sub>GASM</sub>	Fraction of livestock N excretion that volatilizes as NH <sub>3</sub> and NO <sub>x</sub>	kg NH <sub>3</sub> -N+NO <sub>x</sub> -N/kgN excreted	0.2	table 11.3– 2006 IPCC Guidelines
Frac <sub>GRAZ</sub> /Frac <sub>PRP</sub>	Fraction of livestock N excreted and deposited onto soil during grazing	% of kgN/year	#	Equation 11.5 – 2006 IPCC Guidelines
Frac <sub>LEACH</sub>	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 <sub>R</sub>	Fraction of total above-ground crop biomass that is removed from the field as a crop product	kg N/kg crop-N	#	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 N<sub>2</sub>O emissions from agricultural soils, whereas indirect emissions were estimated using Tier 2 method.

#### 5.5.3.1 Activity data

Only a limited number of activity data has been used to provide N<sub>2</sub>O 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: 1990-2014**

year	synthetic fertilizer	manure	sewage sludge	compost	grazing	crop residues	mineralization	Organic soils	other	atmospheric deposition	nitrogen leaching
1990	19689000	5627720	377061	0	4086750	5299	NO	NO	NO	3987206	8935749
1991	21245000	5504517	377284	0	4092205	5545	NO	NO	NO	4119301	9367365
1992	19381000	5375249	381629	0	4006505	5497	NO	NO	NO	3890777	8744964
1993	18400000	5330498	396463	0	3938896	5503	NO	NO	NO	3773171	8421408
1994	18054000	5209587	414636	0	3816895	4797	NO	NO	NO	3693624	8249975
1995	18140000	5548807	411721	0	4010550	5372	NO	NO	NO	3808216	8434935
1996	17860000	5618670	357610	0	4066881	6247	NO	NO	NO	3794632	8372823
1997	17500000	5574838	374792	0	4018484	5848	NO	NO	NO	3743623	8242189
1998	17773500	5534572	375888	0	3960494	5964	NO	NO	NO	3751541	8295125
1999	18047000	5504454	373872	0	3989564	5722	NO	NO	NO	3778278	8376184
2000	17819000	5427817	326925	13913	3964428	8237	NO	NO	NO	3728517	8268096
2001	15200000	5463198	306380	6979	3968581	8478	NO	NO	NO	3469028	7486085
2002	15835000	5300025	324231	6631	3862026	9039	NO	NO	NO	3482083	7601086
2003	12905000	5342270	247494	5091	3849979	9542	NO	NO	NO	3179467	6707813
2004	16355000	5288571	226909	5697	3817560	10314	NO	NO	NO	3503247	7711215
2005	14230000	5342548	240685	12323	3815846	9789	NO	NO	NO	3305280	7095357
2006	14034000	5262122	304367	11082	3794273	9120	NO	NO	NO	3277769	7024489
2007	13312000	5434214	334227	11199	3965505	9704	NO	NO	NO	3280229	6920055
2008	13329000	5623536	294597	14031	4037704	10791	NO	NO	NO	3326874	6992898
2009	13383500	5683716	235168	14733	4072027	11212	NO	NO	NO	3339479	7020107
2010	13354400	5815530	203647	17009	4124963	9688	NO	NO	NO	3367670	7057571
2011	14866600	5639143	247104	11340	4045125	9080	NO	NO	NO	3475202	7445517
2012	13675000	5515099	327707	10524	3963008	9653	NO	NO	NO	3330768	7050297
2013	13944450	5707440	266140	8507	4029913	10012	NO	NO	NO	3396845	7189939
2014	13944450	5812991	266140	8507	4088183	10759	NO	NO	NO	3429609	7239309

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.<sup>130</sup>

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<sup>130</sup> 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.<sup>131</sup> 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<sub>2</sub>O emissions should be associated with an expert judgment.

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<sup>131</sup> See [http://www.environnement.public.lu/dechets/statistiques\\_indicateurs/index.html](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): 1990-2014**

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	235181	70710	5422	45973	5452	5540	18969	31756	1050	15710	130805

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<sub>2</sub>O emissions have been estimated using equation 11.1 from 2006 IPCC GLs:

$$N_2O - N_{N \text{ inputs}} = [(F_{SN} + F_{ON} + F_{CR} + F_{SOM}) * EF_1] * 44/28$$

with:

N<sub>2</sub>O - N<sub>N inputs</sub> : annual direct emissions from N input in kg N<sub>2</sub>O-N

F<sub>SN</sub> : annual amount of synthetic N fertiliser in kg N

F<sub>ON</sub>: annual amount of organic N in kg N (eq. 11.3 IPCC 2006 GLs)

F<sub>CR</sub> : annual amount of N in crop residues in kg N (eq. 11.6 IPCC 2006 GLs)

F<sub>SOM</sub> : annual amount of N in mineral soils (eq. 11.8 IPCC 2006 GLs, “NO”)

EF<sub>1</sub> : 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  $N_{ex}$  = 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 volatilized 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<sub>2</sub>O emissions have been estimated using equation 11.10 – IPCC 2006 GLs:

$$N_2O_L - N = (F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM}) * \text{Frac}_{LEACH} * EF_5 * 44/28$$

with N<sub>2</sub>O<sub>L</sub>-N in kg N<sub>2</sub>O-N/year

EF<sub>5</sub> in kg N<sub>2</sub>O-N/kg N extracted from table 11.3 – 2006 IPCC-GLs

fraction used for calculating N<sub>2</sub>O-N<sub>(L-SOIL)</sub> = Frac<sub>LEACH</sub> (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<sub>2</sub>O default EFs for IPCC Category 3D – Agricultural Soils**

Agricultural soils sub-category	Default EF	Value	Source
3D– Direct Soil Emissions – N addition	EF <sub>1</sub>	0.01 kg N <sub>2</sub> O-N/kg N	table 11.1 – 2006 IPCC-GLs
3D – Direct Soil Emissions – for cattle, poultry and pigs	EF <sub>3PRP,CPP</sub>	0.02 kg N <sub>2</sub> O-N/kg N	
3D – Direct Soil Emissions – for sheep and other animals	EF <sub>3PRP,SO</sub>	0.01 kg N <sub>2</sub> O-N/kg N	
3D – Indirect Soil Emissions – atmospheric deposition	EF <sub>4</sub>	0.01 kg N <sub>2</sub> O-N / kg NH <sub>3</sub> -N + NO <sub>x</sub> -N	table 11.3 – 2006 IPCC-GLs
3D – Indirect Soil Emissions – Leaching	EF <sub>5</sub>	0.0075 kg N <sub>2</sub> O-N / kg N	

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

Table 5-34 presents the main revisions and recalculations, as well as their impact, between submissions 2014v3.1 and 2016 v 1.1 (see also CRF tables 8).

**Table 5-34 – Changes in GHG inventories: submissions 2014v3.1 and 2016v1.1**

Years	2014 v 1.4	2016 v 1.1	Difference
1990	361,81	235,523	-35%
1991	370,21	244,465	-34%
1992	377,84	230,276	-39%
1993	360,39	222,976	-38%
1994	347,21	218,520	-37%
1995	353,21	224,632	-36%
1996	358,48	223,757	-38%
1997	350,69	220,999	-37%
1998	345,95	222,218	-36%
1999	351,03	223,023	-36%
2000	345,10	220,647	-36%
2001	319,00	204,089	-36%
2002	322,78	205,665	-36%
2003	292,49	186,053	-36%
2004	327,46	206,550	-37%
2005	304,68	194,665	-36%
2006	301,08	191,690	-36%
2007	297,73	190,774	-36%
2008	298,52	192,932	-35%
2009	304,76	194,809	-36%
2010	303,84	196,117	-35%
2011	313,19	204,092	-35%
2012	308,59	194,961	-37%

Source: SER.

GHG source & sink category	Revisions 2014v3.1 → 2016v1.1	Type of revision
3D – N Input Manure to Soils	2005-2011 – revised fraction of livestock N excreted and deposited onto soil during grazing (Frac <sub>PRP</sub> ) following the revised AWMS shares for cattle (see 4B1).	a) revised activity data. b) revised parameter.
3D – PRP	1990-2013 – revised nitrogen excretion rate due to revised activity data	revised activity data.
3D – Atmospheric Deposition ...	2010 & 2011 – revised activity data for the horses sub-categories used for estimating the nitrogen excretion rate (see 4B6)	revised activity data.
<b>Impacts of the recalculations on the emissions (N<sub>2</sub>O CO<sub>2</sub> eq.)</b>		

### **5.5.5 Category specific uncertainty**

The uncertainty associated with activity statistics is generally believed to be quite small. Arable land crops, used to estimate soil emissions, are on the high end at 10%.<sup>132</sup>

For emission factors, we follow uncertainties developed for Austria. The CH<sub>4</sub> emission factor for soil emissions is considered uncertain by +/-100%.

### **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.

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 1.6.6.1 of this NIR).

### **5.5.7 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.

## **5.6 Prescribed Burning of Savannahs (IPCC Source Category 3.E)**

This source category does not exist in Luxembourg.

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<sup>132</sup> ARR 2012, §67: information on CRF 3A related uncertainties was included in this section. For more details on uncertainties related to CRF 3 in general, please refer to section 1.7.

## **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<sup>133</sup> forbids clearing and burning<sup>134</sup> of fields, meadows, grasslands, roadsides, forests between the 1<sup>st</sup> of March and the 30<sup>th</sup> 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 2014, this source category was responsible for 0.08% of the total GHG emissions from the agriculture sector and represented 0.05% of the total GHG emissions in CO<sub>2</sub>e (excluding LULUCF).

### **5.8.1 Source category description**

This category consists of emissions resulting from the agricultural use of

- Limestone
- Dolomite

CO<sub>2</sub> 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 emission trends.

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<sup>133</sup> See <http://www.legilux.public.lu/leg/a/archives/2004/0010/a010.pdf#page=2>.

<sup>134</sup> "essartement" in French.

**Table 5-35 - CO<sub>2</sub> emission trends for IPCC Category 3G – Liming: 1990-2014 (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
<b>Trend '90-'14</b>	<b>885%</b>

## 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: 1990-2014**

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

#### **5.8.2.2 Emission factors**

The IPCC default emission factors were used, i.e. 0.12 t CO<sub>2</sub> /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.

#### **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.

#### **5.9 Emissions from urea application (IPCC Source Category 3H)**

There is currently no activity data on the urea use in agriculture available, and hence it is very difficult to even estimate whether there is an underestimation or not. The agricultural sector experts are currently looking into the availability of accounting information from which activity data for urea use might be derived.

#### **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 Total impact of the recalculations**

For the total impact of the recalculations from the agriculture sector on the national emissions, please refer to Chapter 10.



## 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 2014.

### 6.1 Sector Overview

In 2014, Sector 4 – *Land Use, Land Use Change and Forestry* was a net sink in Luxembourg (Table 6-1). Net removals from the LULUCF sector amounted to 455.3 Gg CO<sub>2</sub>e. Since 1990, net emissions have decreased by 1060.5% (the sector was a source of net emissions in 1990 (52.91 Gg CO<sub>2</sub>e) and a source of net removals in 2014). 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 (-455.27 Gg CO<sub>2</sub>e and -32.26 Gg CO<sub>2</sub>e, respectively). All other categories resulted in net emissions: the largest source of emissions was from settlements (71.62 Gg CO<sub>2</sub>e), followed by cropland (35.39 Gg CO<sub>2</sub>e), wetlands (5.68 Gg CO<sub>2</sub>e) and other land (0.30 Gg CO<sub>2</sub>e).

**Table 6-1 - Emissions and Removals from Sector 4 - LULUCF**

Year	5 Total	A Forestland	B Cropland	C Grassland	D Wetlands	E Settlements	F Other land
1990	52.17	- 239.27	81.57	49.10	13.97	145.14	1.67
1991	- 225.07	- 516.51	81.57	49.10	13.97	145.14	1.67
1992	- 554.25	- 845.69	81.57	49.10	13.97	145.14	1.67
1993	- 649.31	- 940.75	81.57	49.10	13.97	145.14	1.67
1994	- 460.13	- 751.57	81.57	49.10	13.97	145.14	1.67
1995	- 563.20	- 854.65	81.57	49.10	13.97	145.14	1.67
1996	- 603.62	- 895.07	81.57	49.10	13.97	145.14	1.67
1997	- 686.36	- 977.80	81.57	49.10	13.97	145.14	1.67
1998	- 570.78	- 862.22	81.57	49.10	13.97	145.14	1.67
1999	- 668.49	- 959.93	81.57	49.10	13.97	145.14	1.67
2000	- 701.81	- 839.18	52.68	- 57.29	12.29	128.80	0.90
2001	- 714.09	- 851.37	52.29	- 55.65	12.17	127.61	0.86
2002	- 716.07	- 853.26	51.91	- 54.02	12.04	126.42	0.83
2003	- 679.29	- 816.38	51.53	- 52.38	11.92	125.23	0.79
2004	- 683.63	- 820.63	51.15	- 50.74	11.79	124.04	0.75
2005	- 638.63	- 775.54	50.77	- 49.10	11.67	122.86	0.72
2006	- 557.15	- 693.96	50.38	- 47.46	11.54	121.67	0.68
2007	- 477.82	- 614.54	50.00	- 45.82	11.41	120.48	0.65
2008	- 491.97	- 576.54	40.41	- 56.48	8.56	91.54	0.54
2009	- 469.39	- 552.46	38.71	- 52.44	8.08	88.22	0.50
2010	- 152.95	- 234.52	37.02	- 48.41	7.60	84.90	0.46
2011	- 274.96	- 355.02	35.32	- 44.37	7.12	81.58	0.42
2012	- 362.86	- 441.43	33.62	- 40.33	6.64	78.26	0.38
2013	- 538.60	- 615.66	31.93	- 36.30	6.16	74.94	0.34
2014	- 460.43	- 535.99	30.23	- 32.26	5.68	71.62	0.30
Trend							
1990-2014	-1082.52%	124.01%	-62.94%	-165.71%	-59.36%	-50.66%	-82.15%
Trend							
2013-2014	-14.51%	-12.94%	-5.31%	-11.12%	-7.82%	-4.43%	-11.97%

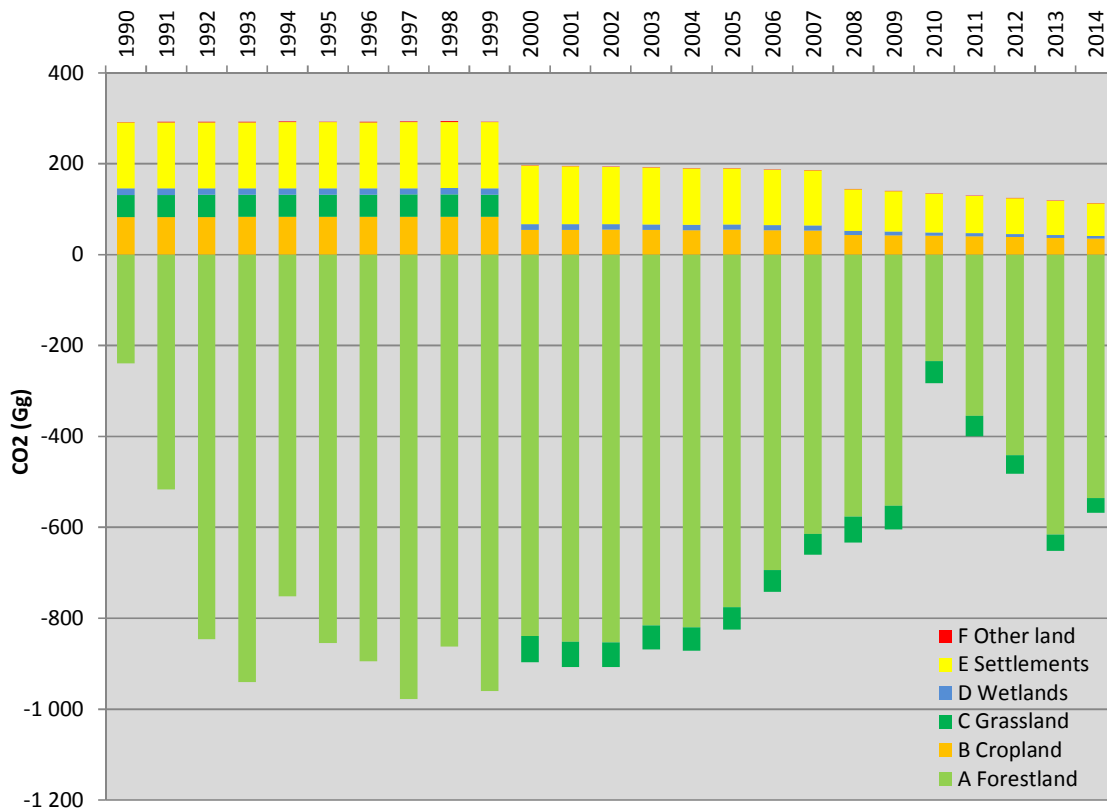
#### 6.1.1 Emission Trends

In 2014, removals from category forest land corresponded to 5.2% of total GHG in Luxembourg (incl. LULUCF). The net removals increased by 1082% from the base year to 2014, 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 6-1).

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 Section 1.5. Table 6-2 presents the key categories of IPCC category 4 - LULUCF.

**Table 6-2 - Key categories of IPCC Sector 4 - LULUCF**

<b>4 - Land Use, Land-Use Change and Forestry</b>						
<i>Key sources</i>						
<b>IPCC Category</b>	<b>Category Name</b>	<b>GHG</b>	<b>LA excl. LULUCF</b>	<b>LA incl. LULUCF</b>	<b>TA excl. LULUCF</b>	<b>TA incl. LULUCF</b>
4A1	Forest Land remaining Forest Land	CO <sub>2</sub>	NA	92-09, 11-14	NA	X
4A2	Land Converted to Forest Land	CO <sub>2</sub>	NA	90, 10	NA	X
Source: Environment Agency						
Notes:	LA = Level Assessment (Tier 1) including respectively excluding LULUCF					
	TA = Trend Assessment 2014 (Tier 1) including respectively excluding LULUCF					

### 6.1.3 Methodology

The territory of Luxembourg has an area of 2586 km<sup>2</sup>. 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 2014, the respective areas were 89.6%, 9.9% and 0.5%. Thus, Luxembourg has some 96 135 ha of forests, some 135 632 ha of agriculturally used land, and some 25 546 ha covered by buildings and roads. Rivers, lakes, wetlands and other lands cover a surface of some 1 288 ha.

Meteorologically, Luxembourg is situated in an area with temperate maritime climate, with an annual average temperature of 11.1°C<sup>135</sup> (year 2014), 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

<sup>135</sup> Average yearly temperature of Luxembourg city: Portail des Statistiques: [www.statistiques.public.lu](http://www.statistiques.public.lu) Table : « A2100 - Températures moyennes à Luxembourg-Ville, 1951-2014 » retrieved 12.11.2015.

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 6-3 .

The OBS categories – that are different for OBS89 and OBS99/07 – have been assigned to the LULUCF categories, as defined in Table 6-3 , according to the following matching tables: Table 6-4 for OB89 to LULUCF and Table 6-5 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: <ul style="list-style-type: none"> <li>• Minimum land area: 0.5 ha</li> <li>• tree crown cover <math>\geq 10</math> %</li> <li>• tree height <math>\geq 5</math> m.</li> </ul> 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>i.e.</i> 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 ( <i>e.g.</i> 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
P	31	forêts	Wald			Forest Area
Pe	312	forêts de conifères	Nadelwald	Coniferous Forest	Coniferous Forest	Forest Area
Pm	3121	épicéas, sapins	Fichte, Tannen	Coniferous Forest	Coniferous Forest	Forest Area
Pr	3122	pins, mezeles	Kiefern, Lärchen	Coniferous Forest	Coniferous Forest	Forest Area
	3123	autres résineux	Other Land Nadelbaume	Coniferous Forest	Coniferous Forest	Forest Area
F/Q	311	forêts de feuillus	Laubwald	Deciduous Forest	Deciduous Forest	Forest Area
Qb	3111	forêts acidophiles	Saure Wälder	Deciduous Forest	Deciduous Forest	Forest Area
Fs	31111	chenaie acidophile très pauvre	artenarmer saurer Eichenwald	Deciduous Forest	Deciduous Forest	Forest Area
Qs	31112	hêtraie et chenaie-hêtraie acidophile	saurer Buchen und Eichen-Buchenwald	Deciduous Forest	Deciduous Forest	Forest Area
Fl	31113	chenaie acidophile	saurer Eichenwald	Deciduous Forest	Deciduous Forest	Forest Area
Ql	31114	hêtraie à luzule blanche	Buchen mit weissen Luzernen	Deciduous Forest	Deciduous Forest	Forest Area
Fl	31115	chenaie à luzule blanche	Eichenwald mit Luzernen	Deciduous Forest	Deciduous Forest	Forest Area
Fl	31116	hêtraie à grande fêtuque	Buchenwald mit hohen Grassern	Deciduous Forest	Deciduous Forest	Forest Area
			besondere trockenheitsliebende Eichenart auf Schiefer und Sandstein	Deciduous Forest	Deciduous Forest	Forest Area
Qx	31117	chenaie à charmes xérophile sur schistes et gres	Wälder auf neutralen Bodenverhältnissen	Deciduous Forest	Deciduous Forest	Forest Area
F/Q	3112	forêts neutroclines à mull	Buchenwald mit irgendeinem bestimmten Unterwuchs	Deciduous Forest	Deciduous Forest	Forest Area
Fm	31121	hêtraie à melique et asperule	besondere Eichenart auf feuchten Standorten	Deciduous Forest	Deciduous Forest	Forest Area
Qa	31122	chenaie à charmes humide	besondere Eichenart mit irgendeinem Unterwuchs	Deciduous Forest	Deciduous Forest	Forest Area
Qm	31123	chenaie-charmaie à melique et asperule	Wälder auf basischen Bodenverhältnissen	Deciduous Forest	Deciduous Forest	Forest Area
F/Q	3113	forêts basiques	Buchenwald auf kalkhaltigem Substrat	Deciduous Forest	Deciduous Forest	Forest Area
FK	31131	hêtraie calcicole	trockenheitsliebende besondere Eichenart	Deciduous Forest	Deciduous Forest	Forest Area
Qk	31132	chenaie à charmes xérophile	Schuttwälder	Deciduous Forest	Deciduous Forest	Forest Area
R	3114	forêts rudérales	Ulmewald in Aufschüttungen	Deciduous Forest	Deciduous Forest	Forest Area
Ru	31141	ormaie rudérale	Laubwald Anpflanzung	Deciduous Forest	Deciduous Forest	Forest Area
P	3115	plantation de feuillus	Pappelwald in trockenen Gebieten	Deciduous Forest	Deciduous Forest	Forest Area
Ps	31151	peupleraie en site sec	Pappelwald in feuchten Gebieten	Deciduous Forest	Deciduous Forest	Forest Area
Ph	31152	peupleraie en site humide	Anpflanzungen Other Land Laubbäume	Deciduous Forest	Deciduous Forest	Forest Area
Pf	31153	plantation d'autres essences feuillues	Schluchtwälder	Deciduous Forest	Deciduous Forest	Forest Area
E	3116	forêts de ravins	Schluchtwald auf kalkhaltigem Substrat	Deciduous Forest	Deciduous Forest	Forest Area
Ek	31161	forêt de ravin sur substrat calcaire	Schluchtwald auf silikatischem Substrat	Deciduous Forest	Deciduous Forest	Forest Area
Es	31162	forêt de ravin sur substrat siliceux	Auewald auf mineralischem Boden	Deciduous Forest	Deciduous Forest	Forest Area
V	3117	forêts alluviales sur sols minéraux	Ulm-Eschenwald in Flusssedimenten	Deciduous Forest	Deciduous Forest	Forest Area
Va	31171	ormaie-frenaie alluviale	Erlen-Eschenwälder in Flusssedimenten	Deciduous Forest	Deciduous Forest	Forest Area
Vb	31172	aulnaie-frenaie alluviale mésotrophe	Erlenwälder in nitratreichen Flusssedimenten	Deciduous Forest	Deciduous Forest	Forest Area
Vn	31173	aulnaie alluviale nitrophile	Erlen-Eschenwälder in Quellgebieten und an Rinnalen	Deciduous Forest	Deciduous Forest	Forest Area
Vc	31174	aulnaie-frenaie des sources et ruisseaux		Deciduous Forest	Deciduous Forest	Forest Area
V	3118	forêts marécageuses à sédimentation organique	Moorbruchwälder	Deciduous Forest	Deciduous Forest	Forest Area
Vm	31181	aulnaie mésotrophe à laiches	Erlenwälder mit Seggen	Deciduous Forest	Deciduous Forest	Forest Area
Vx	31182	boulaie marécageuse	sumpfiger Birkenwald	Deciduous Forest	Deciduous Forest	Forest Area
	323	végétations sclérophylles	Holzartiges Gebüsch	Deciduous Forest	Deciduous Forest	Forest Area
S	324	forêts et végétation arbustive en mutation	Wald und Gehölz im Übergang	Deciduous Forest	Deciduous Forest	Forest Area
	3241	fourrés en sites secs	Wälder auf trockenen Standorten	Deciduous Forest	Deciduous Forest	Forest Area
Sp	32411	fourré d'épineux	domiges Dickicht	Deciduous Forest	Deciduous Forest	Forest Area
Sk	32412	fourré calcaire	Dickicht auf kalkhaltigem Untergrund	Deciduous Forest	Deciduous Forest	Forest Area
Sx	32413	fourré de buis	Buchsbaumdickicht	Deciduous Forest	Deciduous Forest	Forest Area
Se	32414	végétation des coupes forestières	Vegetation der Waldrodungsflächen	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	fourrés en sites humides	Wälder auf feuchten Standorten	Deciduous Forest	Deciduous Forest	Forest Area
So	32421	saulaie humide sur sol tourbeux ou acide	Weidenbäume auf einem feuchten, torfigen oder sauren Boden	Deciduous Forest	Deciduous Forest	Forest Area
Sf	32422	saunaie humide mésotrophe ou eutrophe	Weidenbäume auf einem feuchten, mittelmäßig oder gut mit Nährstoffen versorgten Boden	Deciduous Forest	Deciduous Forest	Forest Area
P	313	forêts mélangées	Mischwald	Mixed Forest	Mixed Forest	Forest Area
Pl	3131	par pied ou par bouquet	truppenweise Mischung (übernommen 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
Hc	2311	prairies semi-naturelles, humides et non-amendées	Halbnatürliche Wiesen	Grassland	Non-Forest Area	Non-Forest Area
Hj	23111	prairie humide peu ou non fertilisée	Feuchtwiese kaum oder nicht gedüngt	Grassland	Non-Forest Area	Non-Forest Area
Hf	23112	prairie humide peu ou non fertilisée à joncs	Feuchtwiese kaum oder nicht gedüngt mit Binsen	Grassland	Non-Forest Area	Non-Forest Area
	23113	prairie humide à reine des prés	Feuchtwiese mit einem krautigen Rosengebüsch	Grassland	Non-Forest Area	Non-Forest Area
Hm	23114	prairie humide non fertilisée à molinie	ungedüngte Feuchtwiese mit bestimmtem Suessgrasgewächs	Grassland	Non-Forest Area	Non-Forest Area
Hmo	231141	type oligotrophe	wenig Nährstoffe	Grassland	Non-Forest Area	Non-Forest Area
Hmm	231142	type mésotrophe	mittelmäßig Nährstoffe	Grassland	Non-Forest Area	Non-Forest Area
Hme	231143	type eutrophe	viel Nährstoffe	Grassland	Non-Forest Area	Non-Forest Area
	2312	prairies mésophiles améliorées	mesophile Weidewiese	Grassland	Non-Forest Area	Non-Forest Area
Hu	23121	prairie mésophile de fauche	mesophile Mahdwiese	Grassland	Non-Forest Area	Non-Forest Area
Hua	23122	prairie mésophile de fauche atypique	untypische mesophile Mahdwiese	Grassland	Non-Forest Area	Non-Forest Area
Hp	23123	pâturage à ray grass et trèfle blanc	Futterpflanzen in breiten Streifen und Klee	Grassland	Non-Forest Area	Non-Forest Area
Hk	23124	prairie à flore très pauvre	Wiesen mit geringer Biodiversität	Grassland	Non-Forest Area	Non-Forest Area
Hr	23125	prairie mésophile abandonnée à flore rudérale	aufgegebene mesophile Wiese mit Ruderalvegetation	Grassland	Non-Forest Area	Non-Forest Area
	32	milieux à végétation arbustive et/ou herbacée	Gehölze und Buschwerk	Grassland	Non-Forest Area	Non-Forest Area
H	321	pelouses et pâturages naturels	Naturnahe Weideflächen	Grassland	Non-Forest Area	Non-Forest Area
Ha	3211	pelouses silicoles à agrostis	Silikatrasen mit irgendeiner Viehfutterpflanze	Grassland	Non-Forest Area	Non-Forest Area
Hn	3212	pelouse silicole à nard	Silikatrasen 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 steinigem 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 pionnière des carrières	Pioniergras in Steinbrüchen	Grassland	Non-Forest Area	Non-Forest Area
Hx	3215	pelouse sur sol toxique	Rasen auf giftigem (vielleicht schwermetallbelasteten) Gelände	Grassland	Non-Forest Area	Non-Forest Area
C	322	landes et broussailles	Heide und Buschwerk	Grassland	Non-Forest Area	Non-Forest Area
Cg	3221	lande sèche à callune	trockene Heide mit irgendeinem speziellen Heidekrautgewächs	Grassland	Non-Forest Area	Non-Forest Area
Cj	3222	lande à callune genévrier	Heidekrautgewächs mit Strauch mit widerstandsfähigen, stacheligen Blättern, der Beeren ausbildet	Grassland	Non-Forest Area	Non-Forest Area
Cd	3223	lande à callune dégradée	degradierte Heide mit speziellem Heidekrautgewächs	Grassland	Non-Forest Area	Non-Forest Area
Cdm	32231	à dominance de molinie	mit Dominanz irgendeines Suessgrasgewächses	Grassland	Non-Forest Area	Non-Forest Area
Cdc	32232	à dominance de canche flexueuse	mit Dominanz einer flexible biegsamen Futterpflanze	Grassland	Non-Forest Area	Non-Forest Area
Cdf	32233	à dominance de fougère aigle	mit Dominanz eines bestimmten Farns	Grassland	Non-Forest Area	Non-Forest Area
Cv	3224	lande sèche à myrtille	trockene Heide mit Heidebeere	Grassland	Non-Forest Area	Non-Forest Area
Ct	3225	lande tourbeuse à myrtille	Torfheide mit Heidebeere	Grassland	Non-Forest Area	Non-Forest Area
Cs	3226	lande à 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	vignobles 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	Streubst und kleine/niedrigwachsende Fruechte	Cropland permanent	Non-Forest Area	Non-Forest Area
Beh	2221	verges, hautes tiges	Streubst mit hohen Staemmen	Cropland permanent	Non-Forest Area	Non-Forest Area
Beb	2222	verges, basses tiges	Streubst 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	extension 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 staedtsicher 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 réseaux 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
Iu	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
It	1213	installations specialisees	Sonderflächen	Settlements	Non-Forest Area	Non-Forest Area
Ik	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	122	stockage d'hydrocarbures ou gaz	Gas- oder Kohlenwasserstofftanks	Settlements	Non-Forest Area	Non-Forest Area
	122	reseau routier, ferroviaire et espaces associes	Schiennwegenetz 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	schiennwegenetz	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	Schiennennetz	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	Yachthafen	Settlements	Non-Forest Area	Non-Forest Area
Ia	124	aerports	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, Schutthalde und Baustellen	Settlements	Non-Forest Area	Non-Forest Area
	131	extraction de materiaux (en activite)	Abbaufächen	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 rudérale ou remblais	Aufschuettungen	Settlements	Non-Forest Area	Non-Forest Area
N	14	espaces verts artificialises, non agricoles	Grünflächen, 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 bordée 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	Feuchtfächen 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 Blatetern	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 schmalblatetrigem 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 abandonnee	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 moins 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	mittelmæssig 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 moins 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	mittelmæssig 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	mittelmæssig 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 à dominance de chêne	Deciduous Forest	Deciduous Forest	Forest
WLB	FFH	3.1.1.2	Laubwald, Buche	Futaie feuillue à dominance de hêtre	Deciduous Forest	Deciduous Forest	Forest
WLS	FFD	3.1.1.3	Laubwald, sonstige Laubbaumarten	Futaie de feuillus divers	Deciduous Forest	Deciduous Forest	Forest
WLM	PFM	3.1.1.4	Laubwald, gemischt, Eiche, Buche	Futaie feuillue mélangee de chênes et de hêtres	Deciduous Forest	Deciduous Forest	Forest
WLN	FTC	3.1.1.5	Eichen-Niederwald	Taillis de chêne	Deciduous Forest	Deciduous Forest	Forest
WLO	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, Vorwälder trockener Standorte	Buissons, prebois sur sols secs	Deciduous Forest	Deciduous Forest	Forest
SBM	BPF	3.2.4.2	Buschwerk, Vorwälder mittlerer Standorte	Buissons, prebois sur sols frais	Deciduous Forest	Deciduous Forest	Forest
SBF	BPH	3.2.4.3	Buschwerk, Vorwälder feuchter Standorte	Buissons, prebois sur sols humides	Deciduous Forest	Deciduous Forest	Forest
SBG	BPE	3.2.4.4	Blockschutt- und Geröllwälder	Forêts, prebois sur éboulis	Deciduous Forest	Deciduous Forest	Forest
SBP	BPA	3.2.4.5	Geotzplanzungen	Plantations cubustives	Deciduous Forest	Deciduous Forest	Forest
WNF	FRE	3.1.2.1	Nadelwald, Fichte/Douglasie/Tanne	Forêt résineuse (épicéas, douglas, sapins)	Coniferous Forest	Coniferous, Spruce/Douglas	Forest
WNK	FRP	3.1.2.2	Nadelwald, Kiefer/Lärche	Forêt résineuse (pins, mélèzes et autres résineux)	Coniferous Forest	Coniferous Pine/Larch	Forest
WNM	FRM	3.1.2.3	Nadelwald, gemischt	Forêt résineuse mélangee	Coniferous Forest	Coniferous mixed	Forest
WMT	FMP	3.1.3.1	Mischwald (Laub/Nadel), truppweise Mischung	Forêt mélangee (feuillus/résineux) par pied, par bouquet	Mixed forest	Mixed forest	Forest
WMF	FMM	3.1.3.2	Mischwald (Laub/Nadel), fließende Mischung	Forêt mélangee (feuillus/résineux), mélange intime	Mixed forest	Mixed forest	Forest
WAU	PCD	3.1.3.3	Aufforstungen, Landungen, Dickungen (Baumart nicht erkennbar)	Culture forestière d'essences non définies	Mixed forest	Mixed forest	Forest
WSF	PSD	3.1.3.4	Sonstige Forest Landflächen (Schlagflur, Windbruch)	Autres surfaces forestières (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	Pépinières, horticulture, arbres de Noël	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 vignobles	Cropland permanent	Non-Forest	Non-Forest
LSH	RHT	2.2.2.1	Streuobst, Hochstamm	Verger à hautes tiges	Cropland permanent	Non-Forest	Non-Forest
LSN	RBT	2.2.2.2	Obst, Niederstamm	Verger à basses tiges	Cropland permanent	Non-Forest	Non-Forest
LFG	RPR	2.3.1.1	Feuchgrünland	Prairie humide	Grassland	Non-Forest	Non-Forest
LMG	RPM	2.3.1.2	Mesophiles Grünland	Prairie mésophile	Grassland	Non-Forest	Non-Forest
KSI	PSI	3.2.1.1	Silicatrockenrasen	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 pionnières (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 rudéralisées et friches sur sols secs à frais	Grassland	Non-Forest	Non-Forest
KRF	PPH	3.2.3.2	Ruderalstandorte, Staudenfluren feuchter Standorte	Surfaces rudéralisées et friches sur sols humides	Grassland	Non-Forest	Non-Forest
BSC	UAD	1.1.1	Siedlungsgebiet, Verdichtungsgrad >80%, City	Tissu urbain dense (degré de l'imperméabilisation des sols >80%)	Settlements	Non-Forest	Non-Forest
BSM	UAA	1.1.2.1.1	Siedlungsgebiet mit Verdichtungsgrad von 50-80%	Zone semi-urbaine, degré de l'imperméabilisation des sols 50-80%	Settlements	Non-Forest	Non-Forest
BSO	UAS	1.1.2.1.2	Siedlungsgebiet Verdichtungsgrad 30-50%	Zone semi-urbaine, degré de l'imperméabilisation des sols 30-50%	Settlements	Non-Forest	Non-Forest
BSB	UAL	1.1.2.2	Siedlungsbänder entlang von Strassen	Urbanisation longiligne, Bandes urbanisées le long des routes	Settlements	Non-Forest	Non-Forest
BSP	UAP	1.1.2.3.1	Öffentliche Plätze	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	Einzelhäuser, Hofe etc. ausserhalb Bebauung	Habitat disséminé en zone rurale, hameau	Settlements	Non-Forest	Non-Forest
BIJ	UIL	1.2.1.1.1	Industrie	Industrie lourde	Settlements	Non-Forest	Non-Forest
BIG	UIA	1.2.1.1.2	Gewerbe, Militär, Dienstleistung	Zone d'activités économiques, terrain militaire	Settlements	Non-Forest	Non-Forest
BIO	UPS	1.2.1.2	Öffentliche Bebauung	Bâtiments et installations à destination socio-culturelle	Settlements	Non-Forest	Non-Forest
BIS	UPE	1.2.1.3.1	Sondergebiete, Stromversorgung	Installations de distribution électrique	Settlements	Non-Forest	Non-Forest
BIW	UPU	1.2.1.3.2	Sondergebiete, Wasserversorgung	Installation de traitement des eaux usées	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, Gewächshäuser)	Constructions agricoles et horticoles, étables, 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, Gebäude, Terminal	Aéroport; terminal, hangar	Settlements	Non-Forest	Non-Forest
BVL	UTT	1.2.4.2	Flughafen, Landebahn	Aéroport; piste et taxiways	Settlements	Non-Forest	Non-Forest
BAF	UEM	1.3.1	Abbaufläche, Tagebau	Zone d'extraction de matériaux	Settlements	Non-Forest	Non-Forest
BAA	UER	1.3.2.1	Aufschüttung, Deponie	Remblais et décharges	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	Friedhöfe	Cimetière	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-, Golfplätze	Terrain de sport, espace récréatif, camping, golf etc.	Settlements	Non-Forest	Non-Forest
BGK	UVJ	1.4.2.2	Kleingartenanlagen	Cité jardinière	Settlements	Non-Forest	Non-Forest
PRO	ROS	4.1.1.1	Rodrichte	Roselière	Wetland	Non-Forest	Non-Forest
FGS	MAG	4.1.1.2	Grossseggenrieder	Magnocaritiaie	Wetland	Non-Forest	Non-Forest
FKS	MBA	4.1.1.3	Kleinsggenrieder	Bas marais	Wetland	Non-Forest	Non-Forest
OFF	RNU	3.3.2	Offene Felsflächen	Roche nue	Other Land	Non-Forest	Non-Forest
OFK	RNU	3.3.2	Offene Felsflächen < 1500m2	Roche nue < 1500m2	Other Land	Non-Forest	Non-Forest
OBS	REN	3.3.2.1	Offene Blockschutt- und Schotterflächen	Eboulis et graviers non colonisés	Other Land	Non-Forest	Non-Forest
GFN	ECN	5.1.1.1.1	Fließgewässer natürlicher Entstehung, naturnah	Cours d'eau naturel	Water	Non-Forest	Non-Forest
GFF	ECA	5.1.1.1.2	Fließgewässer natürlicher Entstehung, naturnah	Cours d'eau artificiel	Water	Non-Forest	Non-Forest
GFK	EEA	5.1.1.2	Fließgewässer künstlicher Entstehung	Cours d'eau artificiels	Water	Non-Forest	Non-Forest
GSN	EPN	5.1.2.1	Stillgewässer natürlicher Entstehung	Plans d'eau anthropogène proche de l'état naturel	Water	Non-Forest	Non-Forest
GSK	EPA	5.1.2.2	Stillgewässer künstlicher Entstehung	Plan d'eau artificiel	Water	Non-Forest	Non-Forest
GAA	EBM	5.1.2.3	Altsenke, 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, réservoir ayant un intérêt écologique	Water	Non-Forest	Non-Forest
GBO	BRS	5.1.2.5.2	Becken, Reservoir ohne biol. Wert	Bassin, réservoir à ciel ouvert sans intérêt écologique	Water	Non-Forest	Non-Forest

### 6.1.3.3 Methodology used to develop the land transition matrix

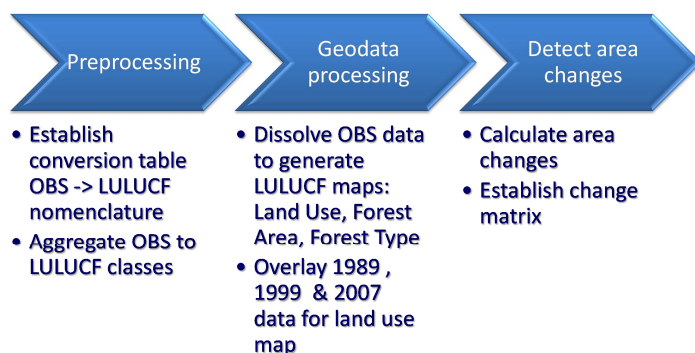
The generation of the LULUCF maps is based on the OBS and RE data. Data processing of OBS89, OBS99 and OBS07 follows the same processing scheme.

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.

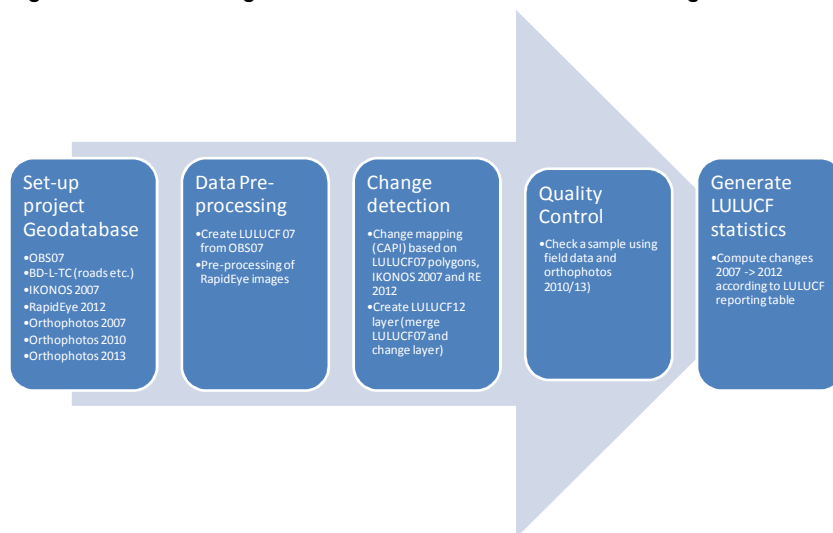
In order to preserve the detail in the data for the generation of the area statistics, no generalisation was performed before the change detection. Change detection of Land Use / Forest types between the selected reference years 1989, 1999 and 2007 has been carried out by overlay (intersect) of the Land Use maps LU89, LU99 and the LU07 data sets. Figure 6-2 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 6-3)

**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<sup>2</sup>. 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 m²)	1989											Totals 1999
		settlements	cropland	permanent crops	grassland	deciduous forest	coniferous forest	mixed forest	forest without trees	other land	wetland	water	
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	<b>23 195</b>
	cropland	289.3	36 254.4	172.8	9 315.0	358.5	229.3	4.7		5.7	9.1	14.1	<b>46 653</b>
	permanent crops	363.1	219.0	3 170.1	758.6	120.6	29.2	2.4		2.3	0.4	1.9	<b>4 668</b>
	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	<b>87 257</b>
	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	<b>58 587</b>
	coniferous forest	90.4	218.7	37.0	578.6	2 866.5	18 665.6	129.8		18.8	3.9	12.5	<b>22 622</b>
	mixed forest	155.4	198.2	32.2	467.8	7 581.7	5 802.6	165.9		21.1	4.5	6.1	<b>14 435</b>
	forest without trees												<b>0</b>
	other land	10.7	0.2	0.0	0.9	11.3	3.6	0.5		30.3	0.0	0.8	<b>58</b>
	wetland	4.3	6.5	0.7	95.5	12.1	10.9	0.3		0.0	65.0	11.3	<b>207</b>
	Water	55.9	11.7	1.1	54.6	44.3	10.7	2.1		0.3	3.2	733.4	<b>917</b>
	<b>Totals 1989</b>	<b>22 250</b>	<b>56 289</b>	<b>5 871</b>	<b>78 845</b>	<b>62 933</b>	<b>29 384</b>	<b>741</b>		<b>893</b>	<b>297</b>	<b>1 097</b>	<b>258 600</b>

Table 6-6 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 m <sup>2</sup> )	1989											Totals 1999
		settlements	Cropland	permanent crops	grassland	deciduous forest	coniferous forest	mixed forest	forest without trees	other land	wetland	water	
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
	<b>Totals 1989</b>	<b>22 250</b>	<b>62 914</b>	<b>5 871</b>	<b>72 220</b>	<b>62 933</b>	<b>29 384</b>	<b>741</b>	<b>0</b>	<b>893</b>	<b>297</b>	<b>1 097</b>	<b>258 600</b>

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 6-9).
- 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 6-8):

**Table 6-8 – Land use change matrix (1999-2007) surfaces (ha) according to LULUCF categories (raw data)**

	LULUCF 2007 (raw data m <sup>2</sup> )	1999											Totals 2007
		Settlements	cropland	permanent crops	grassland	deciduous forest	coniferous forest	mixed forest	forest without trees	other land	wetland	water	
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
<b>Totals 1999</b>	<b>23 182</b>	<b>46 655</b>	<b>4 661</b>	<b>87 206</b>	<b>58 494</b>	<b>21 739</b>	<b>14 178</b>	<b>1 304</b>	<b>58</b>	<b>207</b>	<b>917</b>	<b>258 600</b>

Table 6-9 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 m <sup>2</sup> )	1999											Totals 2007
		settlements	cropland	permanent crops	grassland	deciduous forest	coniferous forest	mixed forest	forest without trees	other land	wetland	water	
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
	<b>Totals 1999</b>	<b>23 182</b>	<b>58 709</b>	<b>4 661</b>	<b>75 151</b>	<b>58 494</b>	<b>21 739</b>	<b>14 178</b>	<b>1 304</b>	<b>58</b>	<b>207</b>	<b>917</b>	<b>258 600</b>

As already mentioned above, changing the data between cropland and grassland leads to the fact that both change matrixes (Table 6-7 & Table 6-9) will give different results for the total area of grassland as well as cropland. Luxembourg will try to address this problem during the implementation of Decision 529/2013/EU. According to this decision Luxembourg will have to calculate the emissions under KPLULUCF from cropland management and grazingland management for its submission under the EU. The available data on agricultural land from the LPIS (land parcel identification system) will have to be analysed in greater detail and will hence improve the data contained on the change matrix.

**Table 6-10 – Land use change matrix (2007-2012) surfaces (ha) according to LULUCF categories (raw data)**

	LULUCF 2007 (raw data m <sup>2</sup> )	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 6-10 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.

**Table 6-11 – 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	63 023	73 482	1 234	24 752	56	linear interpolation
2009	96 067	62 841	73 518	1 234	24 884	56	
2010	96 080	62 660	73 554	1 233	25 017	56	
2011	96 094	62 478	73 591	1 233	25 149	55	
2012	96 107	62 296	73 627	1 233	25 281	55	LU12
2013	96 121	62 114	73 663	1 233	25 414	55	linear extrapolation
2014	96 135	61 933	73 699	1 233	25 546	55	
Trend							
1990-2014	3.02%	-9.64%	2.04%	-9.77%	14.33%	-93.19%	NA
Trend							
2013-2014	0.01%	-0.29%	0.05%	-0.01%	0.52%	0.00%	NA
Trend							
2007-2012	0.07%	-1.44%	0.25%	-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							
2014	37.18%	23.95%	28.50%	0.48%	9.88%	0.02%	NA



Table 6-11 represents the land cover surfaces in ha for the different LULUCF categories, for the period from 1989 to 2013.

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 6-12 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 6-12 – Overview of sub-categories of CRF Sector 4 – LULUCF: status of emission estimates for CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O**

GHG source & sink category	Description	Status		
		Net CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
4A1	forest land remaining forest land	X	NO	NO
4A2	land converted to forest land	X	NO	NO
4B1	cropland remaining cropland	X	NO	NO
4B2	land converted to cropland	X	NO	X
4C1	grassland remaining grassland	IE*, X**	NO	NO
4C2	land converted to grassland	X	NO	NO
4D1	wetlands remaining wetlands	NE,NO	NO	NO
4D2	land converted to wetlands	X	NO	NO
4E1	settlements remaining settlements	NE	NE	NE
4E2	land converted to settlements	X	NE	NE
4F1	other land remaining other land			
4F2	land converted to other land	X	NO	NO
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<sub>2</sub> emissions from lime application on grassland are included in cropland.

(\*\*) 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 96 130 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<sub>2</sub> emissions/removals of the reported period 1990-2014 range from -239 Gg CO<sub>2</sub> (removal) to -536 Gg CO<sub>2</sub> (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<sub>2</sub> balance.

For the reported period 1990 to 2014, the total annual net CO<sub>2</sub> removals (biomass and soil) from land use changes to forest range from about -306 Gg CO<sub>2</sub> to -117 Gg CO<sub>2</sub> (Table 6-13).

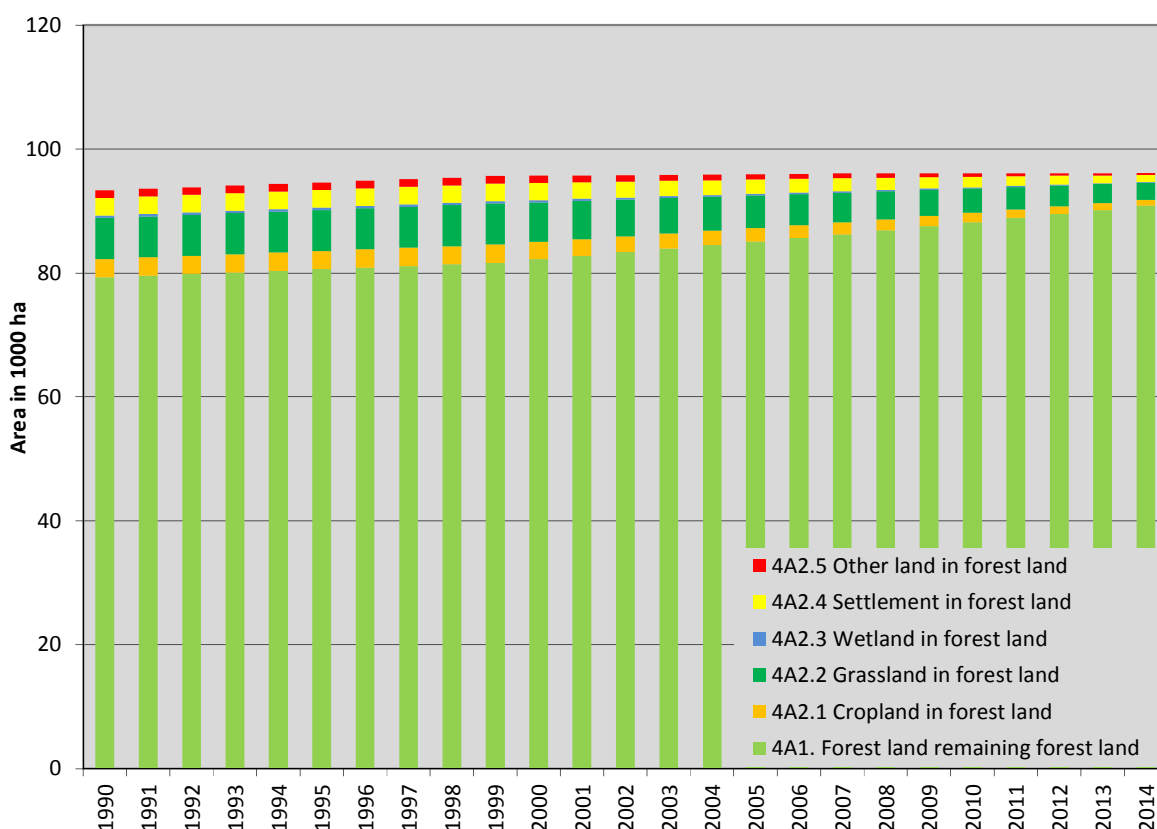
The net carbon stock changes in forest biomass (sub-category 4.A.1) have a major impact on the overall results in sector 4. These changes vary considerable between single years. The reason is that the figures for annual harvest of forest biomass and to a lesser extend forest area differ significantly year by year. The annual harvest will be analysed in chapter 6.2.4.1.1 (page 435) is influenced by timber demand and prices, insect infestation or wind throws. The influence of those factors on the annual variations in the CO<sub>2</sub> 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 6-4 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.

Table 6-13 – CO<sub>2</sub> removals/emissions from IPCC category 4A – Forest Land from 1990-2014

Year	4A Total Forest Land	4A1 FL remaining FL	4A2 Land converted to FL	4A2.1 Cropland converted to FL	4A2.2 Grassland converted to FL	4A2.3 Wetland converted to FL	4A2.4 Settlement converted to FL	4A2.4 Other land converted to FL
1990	- 239.27	66.43	- 305.70	- 61.11	- 108.59	- 13.56	-78.17	-44.28
1991	- 516.51	- 210.81	- 305.70	- 61.11	- 108.59	- 13.56	-78.16	-44.28
1992	- 845.69	- 539.99	- 305.70	- 61.11	- 108.59	- 13.56	-78.16	-44.28
1993	- 940.75	- 635.05	- 305.70	- 61.11	- 108.59	- 13.56	-78.16	-44.28
1994	- 751.57	- 445.87	- 305.70	- 61.11	- 108.59	- 13.56	-78.16	-44.28
1995	- 854.65	- 548.95	- 305.70	- 61.10	- 108.58	- 13.56	-78.16	-44.28
1996	- 895.07	- 589.37	- 305.70	- 61.10	- 108.58	- 13.56	-78.16	-44.28
1997	- 977.80	- 672.10	- 305.70	- 61.10	- 108.58	- 13.56	-78.16	-44.28
1998	- 862.22	- 556.53	- 305.69	- 61.10	- 108.58	- 13.56	-78.16	-44.28
1999	- 959.93	- 654.24	- 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
Trend 1990-2014	157.31%	-828.73%	-56.96%	-61.04%	-50.72%	-66.02%	-53.77%	-69.49%
Trend 2013-2014	39.47%	64.20%	-10.26%	-11.28%	-8.75%	-12.74%	-9.97%	-14.09%

**Figure 6-4 – Trend of forest land and LUC to forest land (conversion period of 20 years) from 1990-2014**



### 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 6-14 and in accordance to the definition provided by FAO 2000.

**Table 6-14 - 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,
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	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...)

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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 6-5 – 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 1000 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 6-6 – Calculation method of forest area according to LUC method**

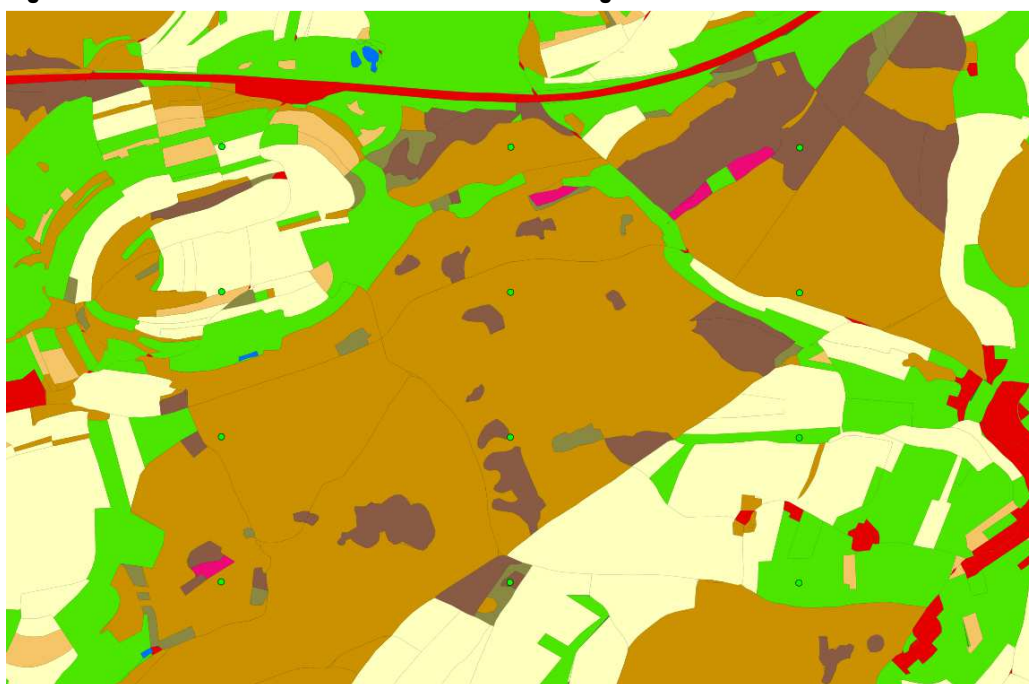


Figure 6-6 shows the same portion of land as Figure 6-5 but with the LUC method applied and based on occupational soil maps and satellite as well as aerial photography. The increased level of detail of the LUC method can be appreciated by comparing both figures.

### 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: <ul style="list-style-type: none"> <li>• Minimum land area: 0.5 ha</li> <li>• tree crown cover <math>\geq 10\%</math></li> <li>• tree height <math>\geq 5</math> m.</li> </ul> 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 are 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<sup>-1</sup>yr<sup>-1</sup>)

V = volume of merchantable wood calculated according to (Dagnelies, Palm, & Rondeux, 2013) (m<sup>3</sup> ha<sup>-1</sup>)

$BEF_{ag}$  = biomass expansion factor for above-ground biomass (Deleuze, et al., 2014)

WBD = wood biomass density (tonnes d.m./m<sup>3</sup>) (Wagenführ & Schreiber, 1985)

The BEF calculated for each tree, according to (Deleuze, et al., 2014), is depending on the diameter of the tree at a height of 150 cm. As the diameter of the trees were measured at a height of 130 cm a calculation model and has been used (Dagnelies, Palm, & Rondeux, 2013) to estimate the diameter at a height of 150 cm.

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<sup>-1</sup>yr<sup>-1</sup>)

V = volume of merchantable wood calculated according to (Dagnelies, Palm, & Rondeux, 2013) (m<sup>3</sup> ha<sup>-1</sup>)

$BEF_{bg}$  = biomass expansion factor for below-ground biomass (Vande Walle, et al., 2005)

WBD = wood biomass density (tonnes d.m./m<sup>3</sup>) (Wagenführ & Schreiber, 1985)

CF = carbon fraction of dry matter, tonne C (tonne d.m.)<sup>-1</sup>

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)

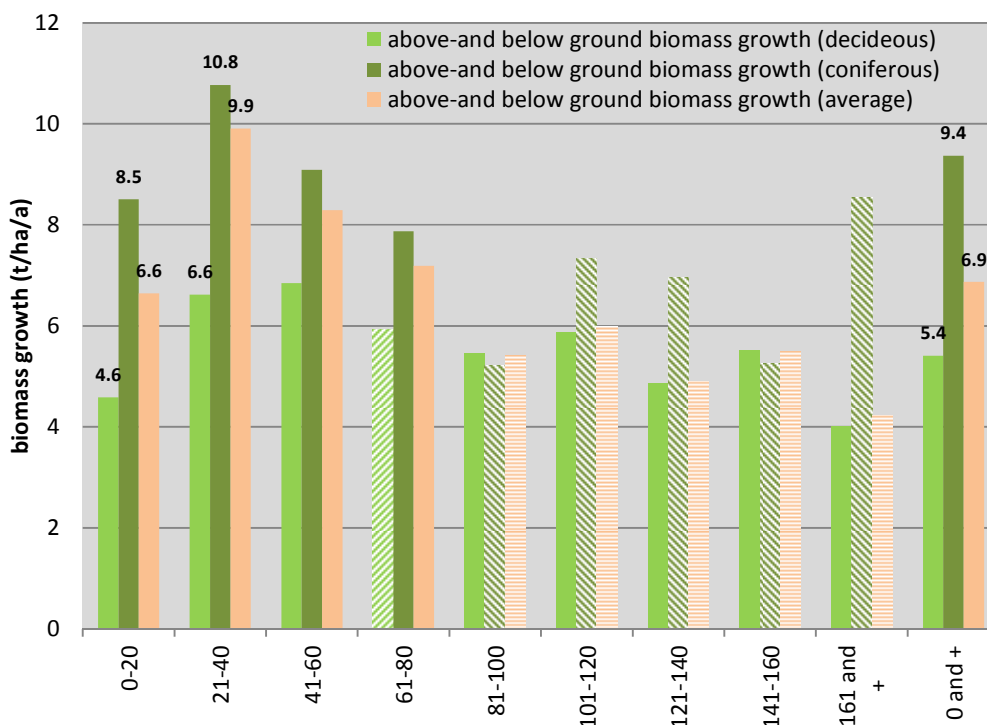
$BEF_{ag}$  = biomass expansion factor for above-ground biomass

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 6-7. 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.)<sup>-1</sup>.

**Figure 6-7 – country-specific biomass growth by forest type and by age (source: NFI)**



**Table 6-15 – country-specific values for above- and below ground biomass increment factors (tonnes d.m. ha<sup>-1</sup> yr<sup>-1</sup>)**

		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 6-15**.

In order to estimate the carbon loss due to drain of living biomass (wood removal, fuelwood removal, disturbances and losses of standing stemwood stocks due to mortality, but remaining at forest site) 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 for conversion by taking into account the number and type of trees found in coniferous forests as well as deciduous forest.

**Table 6-16 – country-specific biomass conversion factor and ratio of below-ground to above-ground biomass used for the calculation of wood removal**

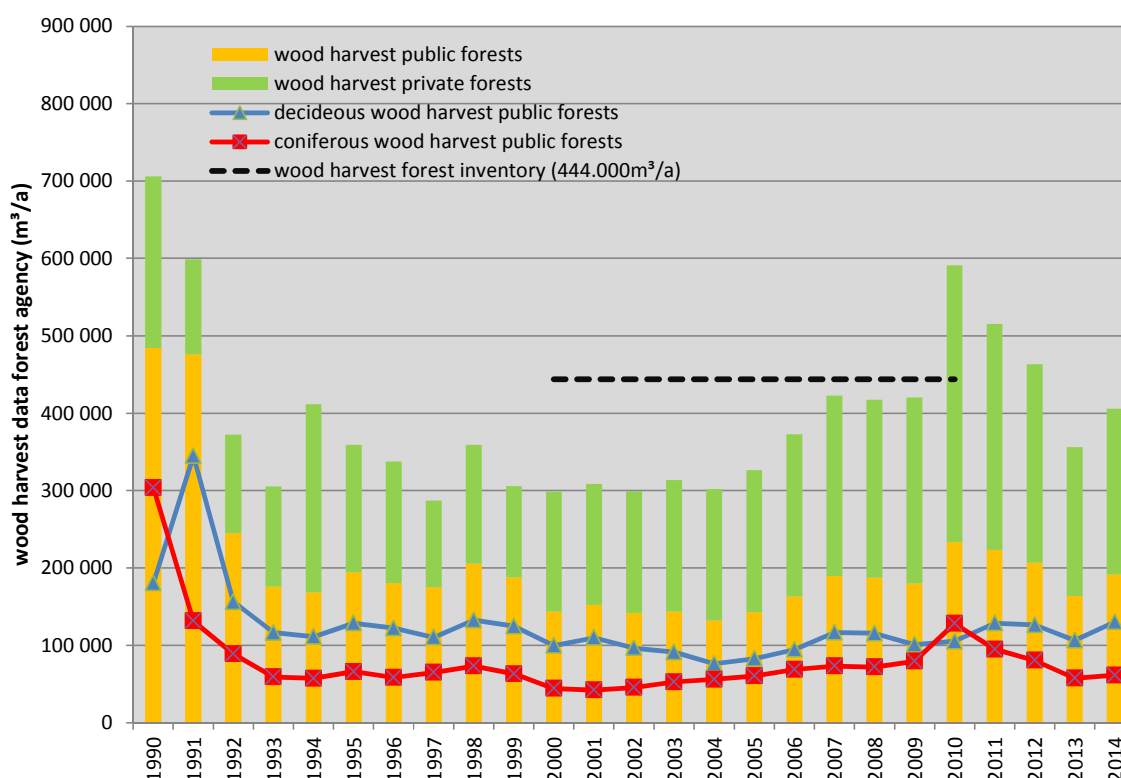
	BCEF <sub>R</sub>	R
Deciduous forests	0.74	0.22
Coniferous forests	0.55	0.20
average	0.68	0.21

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<sup>3</sup>/ha/a
- a) Stemwood drain from private deciduous forests: 3,3 m<sup>3</sup>/ha/a
- b) Stemwood drain from public coniferous forests: 8,7 m<sup>3</sup>/ha/a
- c) Stemwood drain from private coniferous forests: 8,7 m<sup>3</sup>/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<sup>3</sup>/a

**Figure 6-8 – stemwood drain from public forests and estimated stemwood drain from private forests**



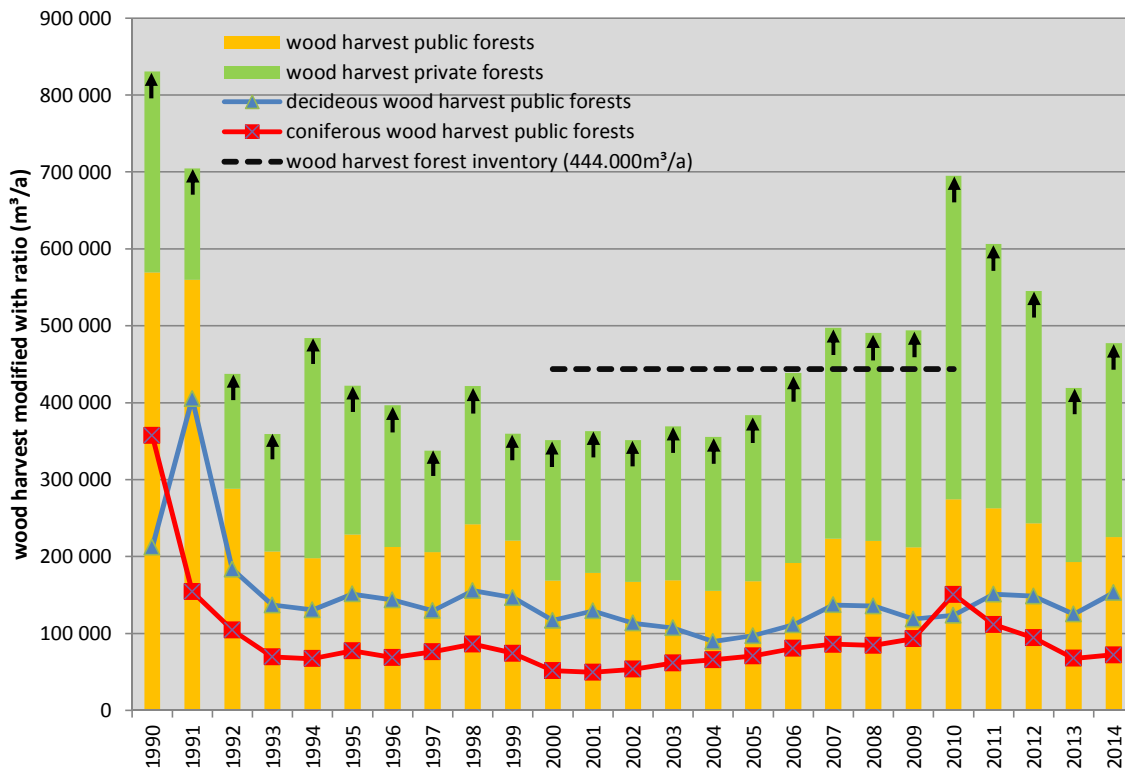
The following figure shows the yearly wood drain from public forests (yellow bars) as collected by the ANF. The green bars show the estimated wood drain from private forests estimated with the specific ratios of wood drain and forest distribution as collected during the forest inventory. The peaks 1990 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 Xynthia. 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<sup>3</sup>/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<sup>3</sup>/a) than the average measured during the forest inventory (444.000 m<sup>3</sup>/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.

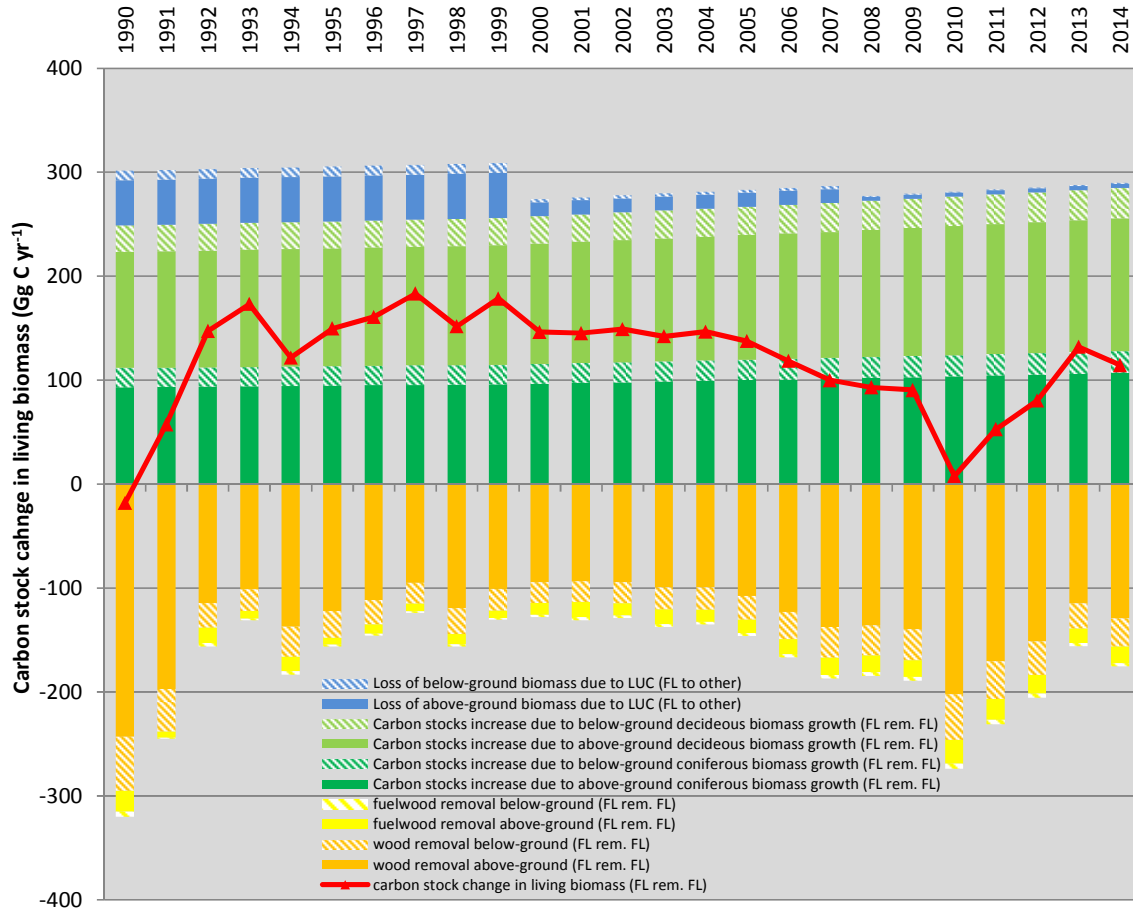
**Figure 6-9 – amended time series of wood harvest (alignment with average wood harvest from forest inventory)**



It is also important to note that the data on wood harvest shown Figure 6-9 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

6.3.4.2.1 & 6.4.4.2 & 6.5.4.2 & 6.6.4.2 & 6.7.3.2.1) has been subtracted from the carbon loss due to wood removal. In Figure 6-10 it is shown as a carbon gain in order to make it visible within the chart.

**Figure 6-10 – 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

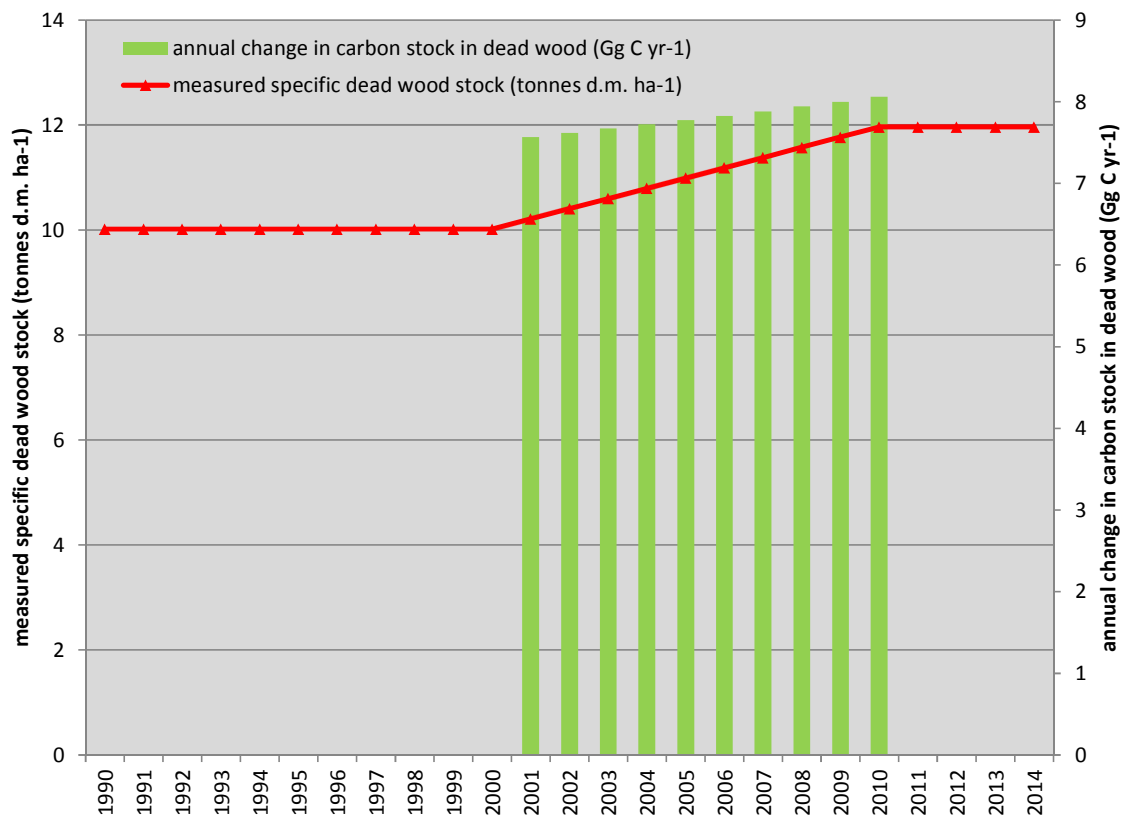
7 cm and older than 3 years (unlikely to be harvested). In order to estimate the biomass for dead wood the biomass expansion factor were not applied which means that small branches of dead wood are not considered. The degree of decomposition influences the quantity of biomass but is not considered in 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 6-17**.

**Table 6-17 –values for dead wood by inventory year (tonnes d.m. ha<sup>-1</sup> yr<sup>-1</sup>)**

	2000	2010
<i>Dead wood on floor</i>	6.3	7.0
<i>Dead wood standing</i>	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 6-11.

**Figure 6-11 – change of carbon stock in dead wood**



For the years before (1990-2000) and after (2011-2014) the two inventories it was assumed that no change in dead wood stock change occurred.

#### 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 country specific data on biomass increase factors and transition periods of 20 years for LUC. It is assumed that no wood removal occurs in forest less than 20 years.

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:

$$\text{Annual change in carbon stock in biomass} = \Delta C_G + \Delta C_{\text{CONVERSION}} - \Delta C_L$$

$$\Delta C_{\text{CONVERSION}} = \sum_i \{ (B_{\text{AFTER}_i} - B_{\text{BEFORE}_i}) \cdot \Delta A_{\text{TO\_OTHERS}_i} \} \cdot CF$$

where :

$\Delta C_G$  = 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 § 6.2.4.1, but only the first age class (0-20) value (Table 6-15) for the annual increment are being used: above-ground biomass growth of 5.5 tonnes d.m. ha<sup>-1</sup> yr<sup>-1</sup> and below-ground biomass growth 1.1 tonnes d.m. ha<sup>-1</sup> yr<sup>-1</sup>.)

$B_{\text{AFTER}(i)}$  = stocks on land type i immediately after conversion, tonnes d.m. ha<sup>-1</sup> (default value = 0).

$B_{\text{BEFORE}(i)}$  = stocks on land type i before conversion, tonnes d.m. ha<sup>-1</sup> (value for carbon stock of woody biomass before conversion depending on land use: see Table 6-18 as well as Table 6-19)).

$\Delta C_L$  = 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<sup>-1</sup> (default value = 0).

$\Delta T_{\text{TO\_OTHERS}(i)}$  = area of land use converted to another land-use category in a certain year, ha yr<sup>-1</sup>.

CF = carbon fraction of dry matter, tonne C (tonne d.m.)<sup>-1</sup>.

i = type of land use converted to another land-use category

**Table 6-18 –biomass stock for different land use categories (tonnes C ha<sup>-1</sup>)**

	Pool	value	Reference
<i>Cropland annual</i>	below-ground	5.0	Table 5.9 IPCC GPG (LULUCF 2006)
<i>Cropland perennial</i>	above-ground	6.4	See below
<i>Forestland</i>	above-ground	98.4	NFI
<i>Forestland</i>	below-ground	21.3	NFI
<i>Grassland</i>	above- and below-ground	6.3	Table 6.4 IPCC GPG (LULUCF 2006)
<i>Wetlands</i>	N/A	0.0	Tier 1

<i>Settlements</i>	above-ground	4.3	section 6.6.4.2
<i>Other land</i>	N/A	0.0	Tier 1

**Table 6-18** 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<sup>-1</sup>). 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 6-19 –biomass decrease factors for perennial cropland (tonnes C ha<sup>-1</sup>)**

	% of perennial cropland	Value	Reference
<i>Vineyards</i>	94	2.64	Germany/Switzerland
<i>orchards</i>	6	63.00	IPCC GPG Table 5.1
<i>Perennial cropland (average)</i>	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<sup>-1</sup> and Switzerland – NIR 2015: 3.61 Mg C ha<sup>-1</sup>) and the default IPCC GPG value used typically for orchards (63.0 Mg C ha<sup>-1</sup>).

#### 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 6-20 – Carbon soil stocks per land use and soil type (t C/ha) in Luxembourg**

Soil type	Total (ha)	Carbon soil stocks per land use and soil type (t C/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 Grès	22'382	58.6	99.4	95.7	75.1	0.0	43.2	0.0
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:

$$IEF(LUC_j) = \frac{\sum_i IEF(LUC_j)_{st,i} \cdot A_{st,i}}{\sum_i A_{st,i}}$$

where :

IEF(LUC<sub>j</sub>) = average yearly emission factor for carbon stock change in soil from land use change j (eg forestland in cropland)

IEF(LUC)<sub>st,i</sub> = yearly emission factor for carbon stock change in soil from land use change j for a soil type i

$A_{st,i}$  = area of soil type i

with:

$$IEF(LUC_j)_{st,i} = \frac{SOC(LU_a)_{st,i} - SOC(LU_b)_{st,i}}{\text{transition}_{\text{period}}}$$

where :

$IEF(LUC)_{st,i}$  = yearly emission factor for carbon stock change in soil from land use change j (eg CL->GL) for a soil type i

$SOC(LU_{a,b})_{st,i}$  = soil organic content by land use type a or b and soil type i

$\text{transition}_{\text{period}}$  = 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)

$$IEF_{CL \rightarrow GL\_Oesling} = \frac{SOC_{CL\_Oesling} - SOC_{GL\_Oesling}}{\text{transition}_{\text{period}}} = \frac{91.5 - 89.2}{20} = 0.115 \text{ tC.ha}^{-1}.\text{yr}^{-1}$$

**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)

$$IEF_{CL \rightarrow GL\_national} = \frac{IEF_{CL \rightarrow GL\_Oesling} \times \text{area}_{Oesling} + IEF_{CL \rightarrow GL\_Buntsandstein} \times \text{area}_{Buntsandstein} + \dots}{\text{area}_{Oesling} + \text{area}_{Buntsandstein} + \dots}$$

The calculation of all land use changes results in the following matrix:

**Table 6-21 – 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 6-11 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.

#### **6.2.5 Uncertainties and time-series consistency**

Uncertainties of IPCC category 5A – *Forestland* are dealt, with in detail, in Chapter 1.7, please refer to sections 1.7.1.1.5 and 1.7.1.2.6.

## 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 2014. Some management practices (*e.g.* slash and burn, *etc.*) and organic soils do not occur and are prohibited in Luxembourg.

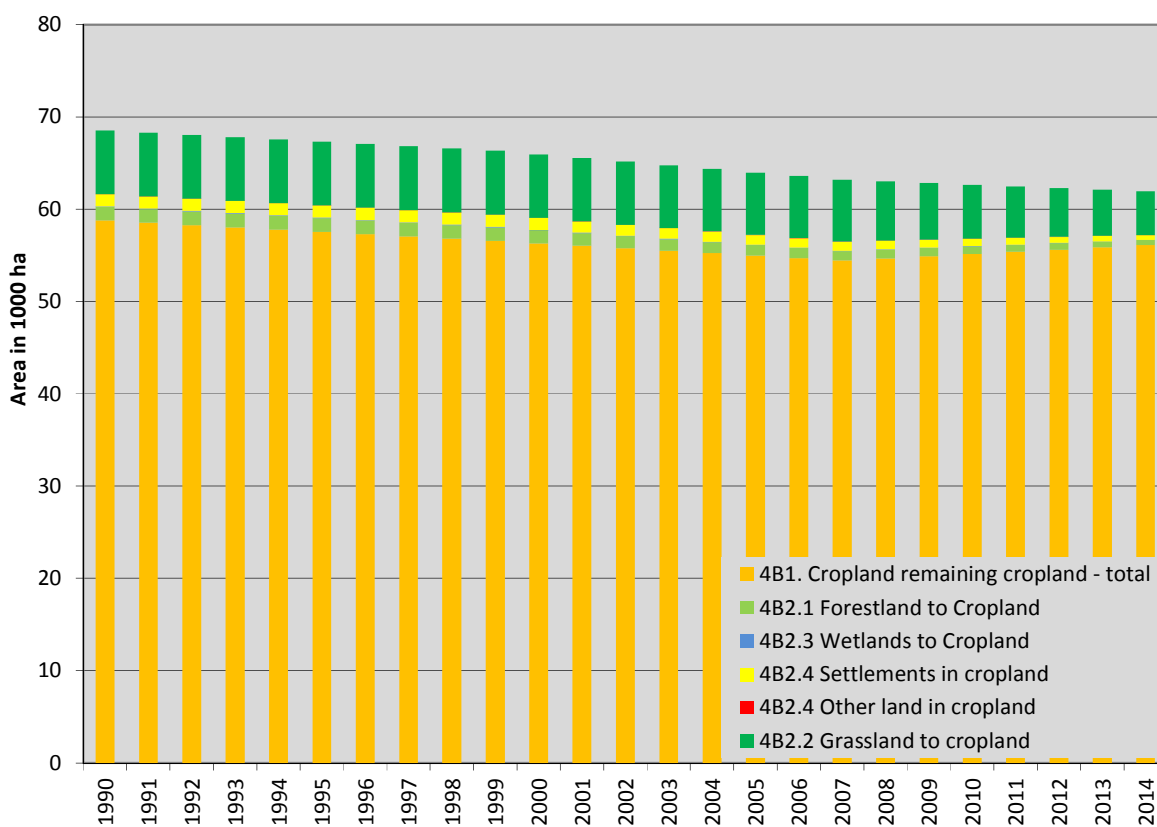
Emissions/Removals were estimated for the sub-categories and related sources/sinks as shown in Table 6-22 .

**Table 6-22 – 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 cropland
4B2 Land converted to cropland
4B2.1 Forest 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 2014, 61 933 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 2014, the land use change area to cropland was 68 ha. The land use changes for a 20 year conversion period are shown in Figure 6-12 .

Figure 6-12 – Trend of cropland and LUC to cropland (covering a conversion period of 20 years) from 1990-2014



The annual emissions from 1990-2014 range between 77.1 Gg CO<sub>2</sub> equivalent and 35.0 Gg CO<sub>2</sub> equivalent respectively (Table 6-23 ). The source is mainly caused by soil C stock changes of land use change areas, particularly by grassland converted to cropland.

Table 6-23 – CO<sub>2</sub> removals/emissions from IPCC category 4B – Cropland from 1990-2014

4B - Cropland									
Greenhouse gas emissions/removals (Gg CO <sub>2</sub> e)									
Year	4B Total Cropland	4B1 CL remaining CL	4B2 Land converted to CL	4B2.1 Forestland converted to CL	4B2.2 Grassland converted to CL	4B2.3 Wetland converted to CL	4B2.4 Settlement converted to CL	4B2.5 Other land converted to CL	N <sub>2</sub> O (in CO <sub>2</sub> eq)
1990	81.57	2.40	79.16	47.12	36.15	- 0.75	-7.78	-0.24	4.66
1991	81.57	2.40	79.16	47.12	36.15	- 0.75	-7.78	-0.24	4.66
1992	81.57	2.40	79.16	47.12	36.15	- 0.75	-7.78	-0.24	4.66
1993	81.57	2.40	79.16	47.12	36.15	- 0.75	-7.78	-0.24	4.66
1994	81.57	2.40	79.16	47.12	36.15	- 0.75	-7.78	-0.24	4.66
1995	81.57	2.40	79.16	47.12	36.15	- 0.75	-7.78	-0.24	4.66
1996	81.57	2.40	79.16	47.12	36.15	- 0.75	-7.78	-0.24	4.66
1997	81.57	2.40	79.16	47.12	36.15	- 0.75	-7.78	-0.24	4.66
1998	81.57	2.40	79.16	47.12	36.15	- 0.75	-7.78	-0.24	4.66
1999	81.57	2.40	79.16	47.12	36.15	- 0.75	-7.78	-0.24	4.66
2000	52.68	3.42	49.25	17.94	35.48	- 0.68	-7.87	-0.22	4.60
2001	52.29	3.26	49.04	17.60	35.36	- 0.65	-7.62	-0.20	4.55
2002	51.91	3.09	48.82	17.25	35.25	- 0.62	-7.36	-0.19	4.50
2003	51.53	2.93	48.60	16.90	35.13	- 0.59	-7.11	-0.18	4.44
2004	51.15	2.76	48.38	16.56	35.02	- 0.56	-6.85	-0.17	4.39
2005	50.77	2.60	48.17	16.21	34.90	- 0.53	-6.60	-0.16	4.34
2006	50.38	2.43	47.95	15.86	34.79	- 0.50	-6.34	-0.15	4.28
2007	50.00	2.27	47.73	15.52	34.67	- 0.47	-6.09	-0.14	4.23
2008	40.41	2.89	37.52	8.78	31.08	- 0.42	-5.82	-0.12	4.03
2009	38.71	2.71	36.00	8.37	29.71	- 0.39	-5.41	-0.11	3.83
2010	37.02	2.53	34.49	7.97	28.35	- 0.35	-5.01	-0.10	3.64
2011	35.32	2.35	32.97	7.56	26.98	- 0.32	-4.60	-0.09	3.44
2012	33.62	2.17	31.46	7.15	25.62	- 0.28	-4.20	-0.08	3.24
2013	31.93	1.99	29.94	6.75	24.25	- 0.25	-3.79	-0.07	3.04
2014	30.23	1.81	28.42	6.34	22.89	- 0.21	-3.39	-0.06	2.85
Trend 1990-2014	-56.70%	-2.21%	-58.35%	-83.96%	-25.37%	-57.67%	-40.83%	-61.77%	-26.14%
Trend 2013-2014	-4.58%	-7.12%	-4.40%	-5.09%	-4.81%	-10.02%	-8.09%	-11.11%	-5.44%

### 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 0 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 1990-2007.

### 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 6.1.3.3. 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>i.e.</i> 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:

$$\text{Annual change in carbon stock in biomass} = \Delta C_G + \Delta C_{\text{CONVERSION}} - \Delta C_L$$

$$\Delta C_{\text{CONVERSION}} = \sum_i \{ (B_{\text{AFTER}i} - B_{\text{BEFORE}i}) \cdot \Delta A_{\text{TO\_OTHERS}i} \} \cdot CF$$

where :

$\Delta C_G$  = 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<sup>-1</sup>yr<sup>-1</sup>).

$B_{\text{AFTER}(i)}$  = stocks on land type i immediately after conversion, tonnes d.m. ha<sup>-1</sup> (default value = 0).

$B_{\text{BEFORE}(i)}$  = stocks on land type i before conversion, tonnes d.m. ha<sup>-1</sup> (value for carbon stock of woody biomass before conversion is 6,4 t C ha<sup>-1</sup> see section 6.2.4.2.1 and **Table 6-18** as well as **Table 6-19**).

$\Delta C_L$  = 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<sup>-1</sup> (default value = 0).

$\Delta T_{\text{TO\_OTHERS}(i)}$  = area of land use I converted to another land-use category in a certain year, ha yr<sup>-1</sup>.

CF = carbon fraction of dry matter, tonne C (tonne d.m.)<sup>-1</sup>.

i = type of land use converted to another land-use category

c) Changes of carbon stock in organic soils:

Organic soils are not occurring in Luxembourg.

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 Laboratoires de Contrôle et d'Essais, Service de Pédologie).

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 2007 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 6.2.4.2.2, annual change in carbon stock of mineral soils =  $IEF(LUC_i)$  \* conversion area, where :

$$IEF(LUC_{\text{perennial cropland} \rightarrow \text{annual cropland}}) = -0.462 \text{ t C/ha *yr}$$

$IEF(LUC_i)$  = 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:

$$\text{Annual change in carbon stock in biomass} = (\text{area of perennial cropland} * \text{carbon accumulation rate}) - (\text{area of perennial cropland before 30 years} * 0.033 * \text{biomass carbon stock at harvest})$$

where:

For the carbon accumulation rate the value of  $0.21 \text{ t C ha}^{-1}\text{yr}^{-1}$  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  $6.4 \text{ t C ha}^{-1}\text{yr}^{-1}$  (see **Table 6-19**) 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:



$$\text{Annual change in carbon stock in biomass} = \Delta C_G + \Delta C_{\text{CONVERSION}} - \Delta C_L$$

$$\Delta C_{\text{CONVERSION}} = \sum_i \{ (B_{\text{AFTER}_i} - B_{\text{BEFORE}_i}) \cdot \Delta A_{\text{TO\_OTHERS}_i} \} \cdot CF$$

where :

$\Delta C_G$  = 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<sup>-1</sup>yr<sup>-1</sup> - see section 6.2.4.2.1 and **Table 6-18** as well as **Table 6-19** = accumulation of 6.4 tC/ha over 30 years).

$B_{\text{AFTER}(i)}$  = stocks on land type i immediately after conversion, tonnes d.m. ha<sup>-1</sup> (default value = 0).

$B_{\text{BEFORE}(i)}$  = stocks on land type i before conversion, tonnes d.m. ha<sup>-1</sup> (value for carbon stock of biomass before conversion is 5 t C ha<sup>-1</sup> see section 6.2.4.2.1 and **Table 6-18**).

$\Delta C_L$  = 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<sup>-1</sup> (default value = 0).

$\Delta A_{\text{TO\_OTHERS}(i)}$  = area of land use i converted to another land-use category in a certain year, ha yr<sup>-1</sup>.

CF = carbon fraction of dry matter, tonne C (tonne d.m.)<sup>-1</sup>.

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 6.2.4.2.2, annual change in carbon stock of mineral soils = IEF(LUC<sub>i</sub>) \* conversion area, where :

$$IEF(LUC_{\text{annual cropland} \rightarrow \text{perennial cropland}}) = +0.462 \text{ t C/ha *yr}$$

IEF(LUC<sub>j</sub>) = 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:

$$\text{Annual change in carbon stock in biomass} = \Delta C_G + \Delta C_{\text{CONVERSION}} - \Delta C_L$$

$$\Delta C_{\text{CONVERSION}} = \sum_i \{ (B_{\text{AFTER}_i} - B_{\text{BEFORE}_i}) \cdot \Delta A_{\text{TO\_OTHERS}_i} \} \cdot CF$$

where :

$\Delta C_G$  = 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<sup>-1</sup>yr<sup>-1</sup>).

$B_{AFTER(i)}$  = stocks on land type i immediately after conversion, tonnes d.m. ha<sup>-1</sup> (default value = 0).

$B_{BEFORE(i)}$  = stocks on land type i before conversion, tonnes d.m. ha<sup>-1</sup> (value for carbon stock before conversion is 6,4 t C ha<sup>-1</sup> for perennial cropland, 119,7 t C ha<sup>-1</sup> for forestland, 6,3 t C ha<sup>-1</sup> for grassland, 4,3 t C ha<sup>-1</sup> for settlements and 0,0 t C ha<sup>-1</sup> for wetland and other land - see section 6.2.4.2.1 and **Table 6-18**).

$\Delta C_L$  = 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<sup>-1</sup> (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<sup>-1</sup>.

CF = carbon fraction of dry matter, tonne C (tonne d.m.)<sup>-1</sup>.

#### 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 :

$\Delta C_{DOM}$  = annual change in carbon stocks in dead wood or litter (tonnes C yr<sup>-1</sup>)

$C_o$  = dead wood/litter stock, under the old land-use category, tonnes C ha<sup>-1</sup> (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<sup>-1</sup> (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 6.2.4.2.2, annual change in carbon stock of mineral soils =  $IEF(LUC_j)$  \* conversion area, where :

$$IEF(LUC_{forestland \rightarrow annual\ cropland}) = -1.237\ t\ C/ha\ *yr$$

$$IEF(LUC_{grassland \rightarrow annual\ cropland}) = -1.308\ t\ C/ha\ *yr$$

$$IEF(LUC_{wetland \rightarrow annual\ cropland}) = +3.770\ t\ C/ha\ *yr$$

$$IEF(LUC_{settlements \rightarrow annual\ cropland}) = +1.609\ t\ C/ha\ *yr$$

$$IEF(LUC_{other\ land \rightarrow annual\ cropland}) = +3.770\ t\ C/ha\ *yr$$

$IEF(LUC_j)$  = 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:

$$\text{Annual change in carbon stock in biomass} = \Delta C_G + \Delta C_{\text{CONVERSION}} - \Delta C_L$$

$$\Delta C_{\text{CONVERSION}} = \sum_i \{ (B_{\text{AFTER}_i} - B_{\text{BEFORE}_i}) \cdot \Delta A_{\text{TO\_OTHERS}_i} \} \cdot CF$$

where :

$\Delta C_G$  = 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<sup>-1</sup>yr<sup>-1</sup>).

$B_{\text{AFTER}(i)}$  = stocks on land type i immediately after conversion, tonnes d.m. ha<sup>-1</sup> (default value = 0).

$B_{\text{BEFORE}(i)}$  = stocks on land type i before conversion, tonnes d.m. ha<sup>-1</sup> (value for carbon stock before conversion is 5,0 t C ha<sup>-1</sup> for annual cropland, 119,7 t C ha<sup>-1</sup> for forestland, 6,3 t C ha<sup>-1</sup> for grassland, 4,3 t C ha<sup>-1</sup> for settlements and 0,0 t C ha<sup>-1</sup> for wetland and other land - see section 6.2.4.2.1 and **Table 6-18**).

$\Delta C_L$  = 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<sup>-1</sup> (default value = 0).

$\Delta A_{\text{TO\_OTHERS}(i)}$  = area of land use i converted to another land-use category in a certain year, ha yr<sup>-1</sup>.

CF = carbon fraction of dry matter, tonne C (tonne d.m.)<sup>-1</sup>.

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:

$$\Delta D_{\text{DOM}} = \frac{(C_n - C_o) \cdot A_{\text{on}}}{T_{\text{on}}}$$

where :

$\Delta C_{\text{DOM}}$  = annual change in carbon stocks in dead wood or litter (tonnes C yr<sup>-1</sup>)

$C_o$  = dead wood/litter stock, under the old land-use category, tonnes C ha<sup>-1</sup> (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<sup>-1</sup> (default value = 0 for all land-use categories but forest)

$A_{\text{on}}$  = area undergoing conversion from old to new land-use category, ha

$T_{\text{on}}$  = 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 6.2.4.2.2, annual change in carbon stock of mineral soils = IEF(LUC<sub>j</sub>) \* conversion area, where :

$$IEF(LUC_{forestland \rightarrow perennial\ cropland}) = -1.237 \text{ t C/ha *yr}$$

$$IEF(LUC_{grassland \rightarrow perennial\ cropland}) = -1.517 \text{ t C/ha *yr}$$

$$IEF(LUC_{wetland \rightarrow perennial\ cropland}) = +5.079 \text{ t C/ha *yr}$$

$$IEF(LUC_{settlements \rightarrow perennial\ cropland}) = +2.917 \text{ t C/ha *yr}$$

$$IEF(LUC_{other\ land \rightarrow perennial\ cropland}) = +5.079 \text{ t C/ha *yr}$$

IEF(LUC<sub>j</sub>) = 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<sub>2</sub>O emissions in soils of land converted to cropland

The annual release of N<sub>2</sub>O due to the conversion of grassland to cropland was calculated with IPCC default value (Tier 1) using equation 11.8 of the IPCC GPG (2006):

$$F_{SOM} = \sum_{LU} \left[ \left( \Delta C_{Mineral, LUC} \cdot \frac{1}{R} \right) \cdot 1000 \right]$$

where:

F<sub>SOM</sub> = 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

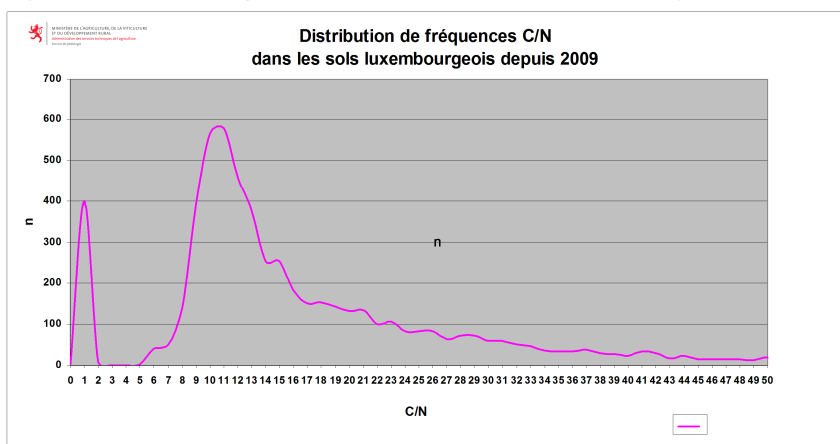
ΔC<sub>Mineral, LU</sub> = average annual loss of soil carbon for each land-use type (LU), tonnes C

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 the 1960s, where C and N content was determined<sup>136</sup>. This value is still valid, as new study done on regular soil analysis (among the different soil types of Luxembourg) since 2009, has shown. Indeed, the distribution curve of C/N ratio (as shown in Figure 6-13) shows a mean for C/N = 12 approximately.

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<sup>136</sup> ASTA (Administration des services techniques de l'Agriculture, <http://www.asta.etat.lu/Laboratoires/Boden/Boden.html>). ARR 2011, §107

**Figure 6-13 - Frequency distribution of C/N ratio in Luxembourg's soils since 2009**



Source: ASTA

## 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.

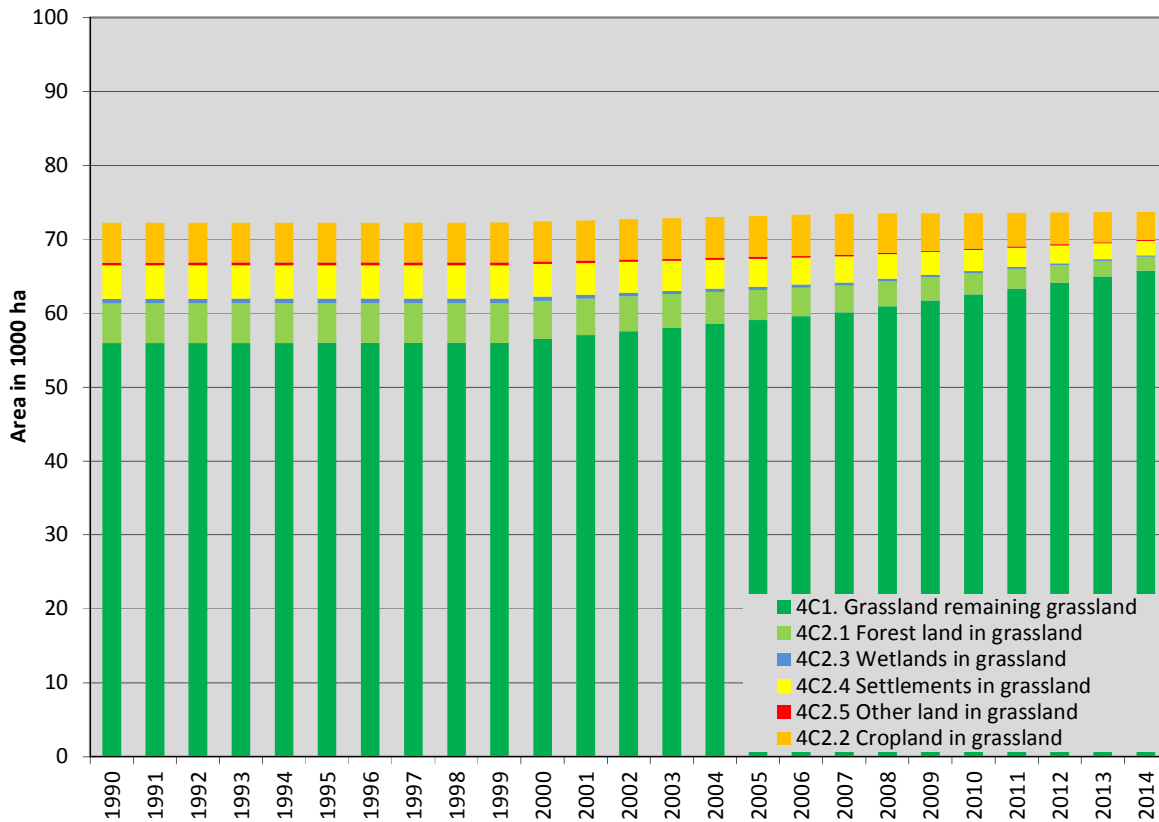
Emissions/Removals were estimated for the following IPCC sub-categories and their related sources/sinks (Table 6-24 ).

**Table 6-24 – 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
4C2 Land converted to grassland
4C2.1 Forest 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 2014, 73 699 ha of Luxembourg were grassland (Figure 6-14 ). Total grassland includes one cut meadows; two and more cut meadows, cultivated pastures, litter meadows, rough pastures and pastures and abandoned grassland.

**Figure 6-14 – Trend of grassland and LUC to grassland (conversion period of 20 years) from 1990-2014**



The annual emissions of grassland in Luxembourg amounted to 49.1 Gg CO<sub>2</sub> in 1990 and - 32.3 Gg CO<sub>2</sub> in 2014 (Table 6-25 ). The source is mainly caused by soil C stock changes in land use change areas, particularly by forestland converted to grassland.

Table 6-25 – CO<sub>2</sub> removals/emissions from IPCC category 4C – Grassland from 1990-2014

4C - Grassland								
Greenhouse gas emissions/removals (Gg CO <sub>2</sub> e)								
Year	4C Total Grassland	4C1 GL remaining GL	4C2 Land converted to GL	4C2.1 Forestland converted to GL	4C2.2 Cropland converted to GL	4C2.3 Wetland converted to GL	4C2.4 Settlement converted to GL	4C2.4 Other land converted to GL
1990	49.10	NO	49.10	145.13	- 27.14	- 11.26	-50.18	-7.45
1991	49.10	NO	49.10	145.13	- 27.14	- 11.26	-50.18	-7.45
1992	49.10	NO	49.10	145.13	- 27.14	- 11.26	-50.18	-7.45
1993	49.10	NO	49.10	145.13	- 27.14	- 11.26	-50.18	-7.45
1994	49.10	NO	49.10	145.13	- 27.14	- 11.26	-50.18	-7.45
1995	49.10	NO	49.10	145.13	- 27.14	- 11.26	-50.18	-7.45
1996	49.10	NO	49.10	145.13	- 27.14	- 11.26	-50.18	-7.45
1997	49.10	NO	49.10	145.13	- 27.14	- 11.26	-50.18	-7.45
1998	49.10	NO	49.10	145.13	- 27.14	- 11.26	-50.18	-7.45
1999	49.10	NO	49.10	145.13	- 27.14	- 11.26	-50.18	-7.45
2000	- 57.29	NO	- 57.29	35.22	- 27.26	- 10.24	-47.92	-7.10
2001	- 55.65	NO	- 55.65	34.84	- 27.38	- 9.79	-46.58	-6.75
2002	- 54.02	NO	- 54.02	34.47	- 27.50	- 9.33	-45.24	-6.40
2003	- 52.38	NO	- 52.38	34.09	- 27.63	- 8.88	-43.90	-6.05
2004	- 50.74	NO	- 50.74	33.71	- 27.75	- 8.43	-42.56	-5.70
2005	- 49.10	NO	- 49.10	33.33	- 27.87	- 7.97	-41.22	-5.35
2006	- 47.46	NO	- 47.46	32.95	- 28.00	- 7.52	-39.89	-5.01
2007	- 45.82	NO	- 45.82	32.57	- 28.12	- 7.06	-38.55	-4.66
2008	- 56.48	NO	- 56.48	15.39	- 25.71	- 6.44	-35.41	-4.31
2009	- 52.44	NO	- 52.44	14.96	- 24.52	- 5.91	-33.01	-3.95
2010	- 48.41	NO	- 48.41	14.52	- 23.33	- 5.39	-30.61	-3.60
2011	- 44.37	NO	- 44.37	14.08	- 22.14	- 4.86	-28.20	-3.25
2012	- 40.33	NO	- 40.33	13.65	- 20.95	- 4.33	-25.80	-2.90
2013	- 36.30	NO	- 36.30	13.21	- 19.76	- 3.80	-23.40	-2.55
2014	- 32.26	NO	- 32.26	12.77	- 18.57	- 3.27	-21.00	-2.20
Trend 1990-2014	-165.71%	NA	-165.71%	-91.20%	-31.58%	-70.95%	-58.16%	-70.46%
Trend 2013-2014	-11.12%	NA	-11.12%	-3.30%	-6.03%	-13.91%	-10.27%	-13.74%

#### 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 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 2007 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 IPCC 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:



$$\text{Annual change in carbon stock in biomass} = \Delta C_G + \Delta C_{\text{CONVERSION}} - \Delta C_L$$

$$\Delta C_{\text{CONVERSION}} = \sum_i \{ (B_{\text{AFTER}_i} - B_{\text{BEFORE}_i}) \cdot \Delta A_{\text{TO\_OTHERS}_i} \} \cdot CF$$

where:

$\Delta C_G$  = 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 6.3 t C ha<sup>-1</sup>yr<sup>-1</sup>).

$B_{\text{AFTER}(i)}$  = stocks on land type i immediately after conversion, tonnes d.m. ha<sup>-1</sup> (default value = 0).

$B_{\text{BEFORE}(i)}$  = stocks on land type i before conversion, tonnes d.m. ha<sup>-1</sup> (value for carbon stock before conversion is 6,4 t C ha<sup>-1</sup> for perennial cropland, 119,7 t C ha<sup>-1</sup> for forestland, 5,0 t C ha<sup>-1</sup> for annual cropland, 4,3 t C ha<sup>-1</sup> for settlements and 0,0 t C ha<sup>-1</sup> for wetland and other land- see section 6.2.4.2.1 and **Table 6-18**).

$\Delta C_L$  = 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<sup>-1</sup> (default value = 0).

$\Delta T_{\text{TO\_OTHERS}(i)}$  = area of land use i converted to another land-use category in a certain year, ha yr<sup>-1</sup>.

CF = carbon fraction of dry matter, tonne C (tonne d.m.)<sup>-1</sup>.

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:

$$\Delta D_{\text{DOM}} = \frac{(C_n - C_o) \cdot A_{\text{on}}}{T_{\text{on}}}$$

where :

$\Delta C_{\text{DOM}}$  = annual change in carbon stocks in dead wood or litter (tonnes C yr<sup>-1</sup>)

$C_o$  = dead wood/litter stock, under the old land-use category, tonnes C ha<sup>-1</sup> (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<sup>-1</sup> (default value = 0 for all land-use categories but forest)

$A_{\text{on}}$  = area undergoing conversion from old to new land-use category, ha

$T_{\text{on}}$  = 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 6.2.4.2.2, annual change in carbon stock of mineral soils = IEF(LUC<sub>i</sub>) \* conversion area, where :

$$\text{IEF}(\text{LUC}_{\text{forestland} \rightarrow \text{grassland}}) = -0.476 \text{ t C/ha *yr}$$

$$\text{IEF}(\text{LUC}_{\text{annual cropland} \rightarrow \text{grassland}}) = +1.308 \text{ t C/ha *yr}$$

$$\text{IEF}(\text{LUC}_{\text{perennial cropland} \rightarrow \text{grassland}}) = +1.517 \text{ t C/ha *yr}$$

$$\text{IEF}(\text{LUC}_{\text{wetland} \rightarrow \text{grassland}}) = +5.079 \text{ t C/ha *yr}$$

$$\text{IEF}(\text{LUC}_{\text{settlements} \rightarrow \text{grassland}}) = +2.917 \text{ t C/ha *yr}$$

$$IEF(LUC_{other\ land \rightarrow grassland}) = +5.079\ t\ C/ha\ *yr$$

IEF(LUCj) = average yearly emission factor for carbon stock change in soil from land use change

## 6.5 Wetlands (4.D)

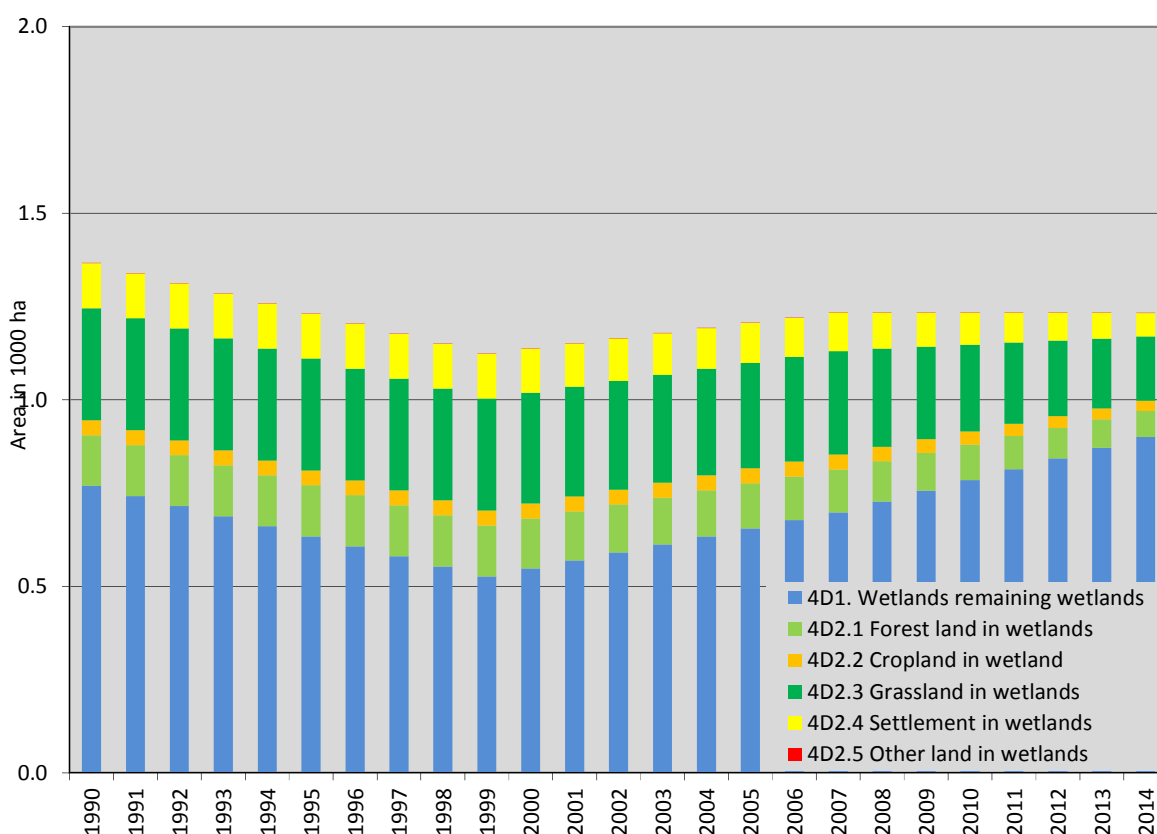
### 6.5.1 Category description

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 2014, 1 233 ha of Luxembourg were wetland (Figure 6-15 ). 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 6-15 – Trend of wetland and LUC to wetland (covering a conversion period of 20 years) from 1990-2014



The annual emissions from wetland in Luxembourg amounted to 14.0 Gg CO<sub>2</sub> in 1990 and 5.7 Gg CO<sub>2</sub> in 2014 (Table 6-25 ). The source is mainly caused by soil C stock changes in land use change areas, particularly by forestland and grassland converted to wetland.

Table 6-26 – CO<sub>2</sub> removals/emissions from IPCC category 4D – Wetland from 1990-2014

4D - Wetland								
Greenhouse gas emissions/removals (Gg CO <sub>2</sub> e)								
Year	4D Total Wetland	4D1 WL remaining WL	4D2 Land converted to WL	4D2.1 Forestland converted to WL	4D2.2 Cropland converted to WL	4D2.3 Grassland converted to WL	4D2.4 Settlement converted to WL	4D2.5 Other land converted to WL
1990	13.97	NE	13.97	6.39	0.59	5.94	1.05	0.00
1991	13.97	NE	13.97	6.39	0.59	5.94	1.05	0.00
1992	13.97	NE	13.97	6.39	0.59	5.94	1.05	0.00
1993	13.97	NE	13.97	6.39	0.59	5.94	1.05	0.00
1994	13.97	NE	13.97	6.39	0.59	5.94	1.05	0.00
1995	13.97	NE	13.97	6.39	0.59	5.94	1.05	0.00
1996	13.97	NE	13.97	6.39	0.59	5.94	1.05	0.00
1997	13.97	NE	13.97	6.39	0.59	5.94	1.05	0.00
1998	13.97	NE	13.97	6.39	0.59	5.94	1.05	0.00
1999	13.97	NE	13.97	6.39	0.59	5.94	1.05	0.00
2000	12.29	NE	12.29	4.88	0.59	5.82	1.00	0.00
2001	12.17	NE	12.17	4.83	0.59	5.77	0.98	0.00
2002	12.04	NE	12.04	4.77	0.59	5.71	0.96	0.00
2003	11.92	NE	11.92	4.72	0.59	5.66	0.95	0.00
2004	11.79	NE	11.79	4.66	0.59	5.61	0.93	0.00
2005	11.67	NE	11.67	4.61	0.59	5.55	0.91	0.00
2006	11.54	NE	11.54	4.55	0.60	5.50	0.89	0.00
2007	11.41	NE	11.41	4.49	0.60	5.45	0.88	0.00
2008	8.56	NE	8.56	2.36	0.53	4.89	0.78	0.00
2009	8.08	NE	8.08	2.23	0.51	4.61	0.73	0.00
2010	7.60	NE	7.60	2.10	0.48	4.34	0.68	0.00
2011	7.12	NE	7.12	1.97	0.45	4.06	0.64	0.00
2012	6.64	NE	6.64	1.83	0.43	3.78	0.59	0.00
2013	6.16	NE	6.16	1.70	0.40	3.51	0.55	0.00
2014	5.68	NE	5.68	1.57	0.38	3.23	0.50	0.00
Trend 1990-2014	-59.36%	NA	-59.36%	-75.46%	-36.38%	-45.63%	-52.08%	NA
Trend 2013-2014	-7.82%	NA	-7.82%	-7.81%	-6.50%	-7.91%	-8.27%	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 6.1.3.3.

### 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 used as grassland for animals.

#### 6.5.4.2 Land Use Changes to Wetlands (4D2)

##### a) Changes in carbon stock in biomass of land converted to grassland:

The area in conversion status from forest land to wetland for a time period of 20 years ranges from 137 ha to 69 ha between the years 1990 and 2014 causing annual emission rates due to the loss of biomass and C stock changes in soil from 5.7 Gg CO<sub>2</sub> to 14.0 Gg CO<sub>2</sub>.

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:

$$\text{Annual change in carbon stock in biomass} = \Delta C_G + \Delta C_{\text{CONVERSION}} - \Delta C_L$$

$$\Delta C_{\text{CONVERSION}} = \sum_i \{ (B_{\text{AFTER}_i} - B_{\text{BEFORE}_i}) \cdot \Delta A_{\text{TO\_OTHERS}_i} \} \cdot CF$$

where :

$\Delta C_G$  = 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<sup>-1</sup>yr<sup>-1</sup>).

$B_{\text{AFTER}(i)}$  = stocks on land type i immediately after conversion, tonnes d.m. ha<sup>-1</sup> (default value = 0).

$B_{\text{BEFORE}(i)}$  = stocks on land type i before conversion, tonnes d.m. ha<sup>-1</sup> (value for carbon stock before conversion is 6,4 t C ha<sup>-1</sup> for perennial cropland, 119,7 t C ha<sup>-1</sup> for forestland, 6,3 t C ha<sup>-1</sup> for grassland, 4,3 t C ha<sup>-1</sup> for settlements, 5,0 t C ha<sup>-1</sup> for annual cropland and 0,0 t C ha<sup>-1</sup> other land - see section 6.2.4.2.1 and **Table 6-18**).

$\Delta C_L$  = 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<sup>-1</sup> (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<sup>-1</sup>.

CF = carbon fraction of dry matter, tonne C (tonne d.m.)<sup>-1</sup>.

#### 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 :

$\Delta C_{DOM}$  = annual change in carbon stocks in dead wood or litter (tonnes C yr<sup>-1</sup>)

$C_o$  = dead wood/litter stock, under the old land-use category, tonnes C ha<sup>-1</sup> (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<sup>-1</sup> (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 6.2.4.2.2, annual change in carbon stock of mineral soils = IEF(LUC<sub>i</sub>) \* conversion area, where :

$$IEF(LUC_{forestland \rightarrow wetland}) = - 5.554 \text{ t C/ha *yr}$$

$$IEF(LUC_{perennial cropland \rightarrow wetland}) = - 3.778 \text{ t C/ha *yr}$$

$$IEF(LUC_{annual cropland \rightarrow wetland}) = -3.770 \text{ t C/ha *yr}$$

$$IEF(LUC_{grassland \rightarrow wetland}) = - 5.079 \text{ t C/ha *yr}$$

$$IEF(LUC_{settlements \rightarrow wetland}) = - 2.917 \text{ t C/ha *yr}$$

$$IEF(LUC_{other land \rightarrow wetland}) = 2.162 \text{ t C/ha *yr}$$

IEF(LUC<sub>j</sub>) = average yearly emission factor for carbon stock change in soil from land use change

## **6.6 Settlements (4.E)**

### **6.6.1 Category description**

In this category emissions/removals from land converted to settlements are considered.

In 2014, 25 546 ha of Luxembourg were settlements (Figure 6-16 ). The area in conversion status from “Land converted to Settlement” for a time period of 20 years ranges from 10 717 ha to

6 536 ha between the years 1990 and 2014 causing annual emission rates due to C stock changes of biomass and soils from 145.1 Gg CO<sub>2</sub> to 71.6 Gg CO<sub>2</sub> (Table 6-27).

Annual LUCs to settlement occur from the sub-categories "ForestLand", "Cropland", "Grassland", "Wetland" and "Other land".

**Figure 6-16 – Trend of wetland and LUC to settlement (covering a conversion period of 20 years) from 1990-2014**

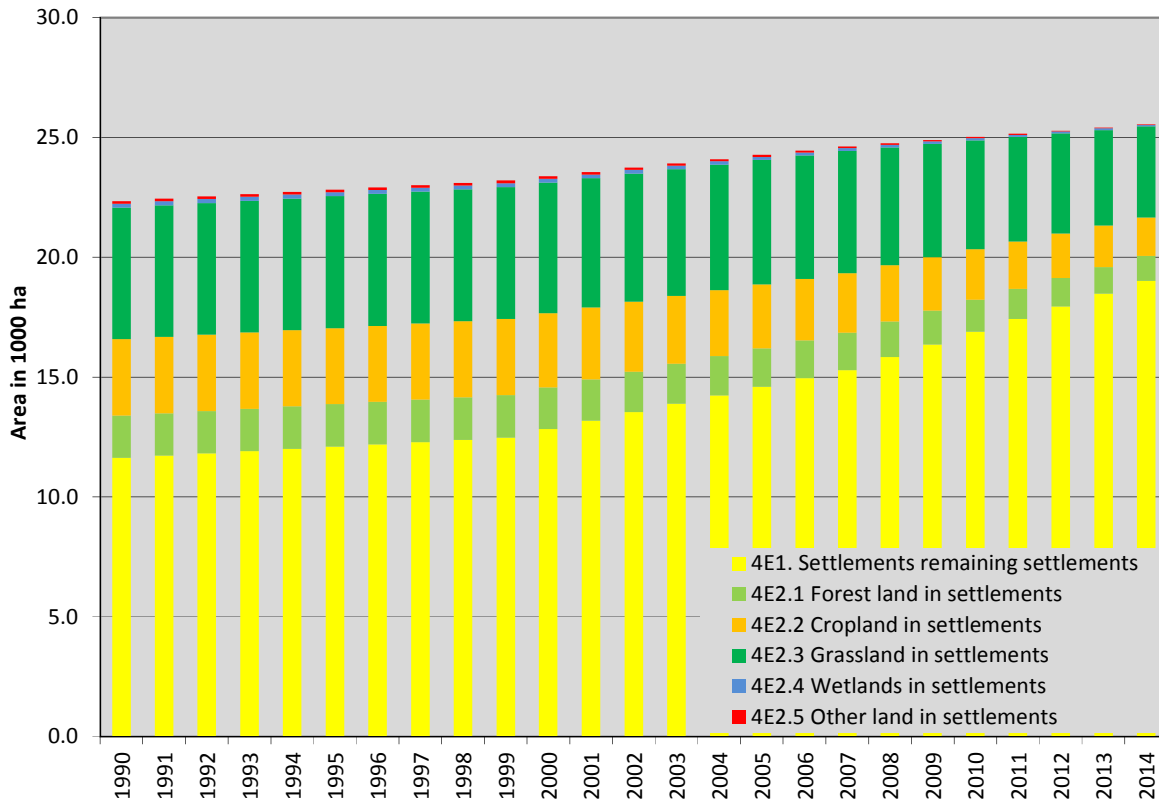


Table 6-27 – CO<sub>2</sub> removals/emissions from IPCC category 5E – Settlement from 1990-2014

4E - Settlement								
Greenhouse gas emissions/removals (Gg CO <sub>2</sub> e)								
Year	4E Total Settlement	4E1 Settlement remaining Settlement	4E2 Land converted to Settlement	4E2.1 Forestland converted to Settlement	4E2.2 Cropland converted to Settlement	4E2.3 Grassland converted to Settlement	4E2.4 Wetland converted to Settlement	4E2.5 Other land converted to Settlement
1990	145.14	NE	145.14	67.34	19.40	60.80	-1.43	-0.96
1991	145.14	NE	145.14	67.34	19.40	60.80	-1.43	-0.96
1992	145.14	NE	145.14	67.34	19.40	60.80	-1.43	-0.96
1993	145.14	NE	145.14	67.34	19.40	60.80	-1.43	-0.96
1994	145.14	NE	145.14	67.34	19.40	60.80	-1.43	-0.96
1995	145.14	NE	145.14	67.34	19.40	60.80	-1.43	-0.96
1996	145.14	NE	145.14	67.34	19.40	60.80	-1.43	-0.96
1997	145.14	NE	145.14	67.34	19.40	60.80	-1.43	-0.96
1998	145.14	NE	145.14	67.34	19.40	60.80	-1.43	-0.96
1999	145.14	NE	145.14	67.34	19.40	60.80	-1.43	-0.96
2000	128.80	NE	128.80	53.14	17.61	60.29	-1.35	-0.89
2001	127.61	NE	127.61	52.82	17.15	59.79	-1.30	-0.84
2002	126.42	NE	126.42	52.51	16.68	59.28	-1.25	-0.80
2003	125.23	NE	125.23	52.19	16.22	58.77	-1.20	-0.75
2004	124.04	NE	124.04	51.88	15.76	58.27	-1.15	-0.71
2005	122.86	NE	122.86	51.56	15.30	57.76	-1.10	-0.66
2006	121.67	NE	121.67	51.25	14.84	57.25	-1.05	-0.62
2007	120.48	NE	120.48	50.93	14.38	56.75	-1.00	-0.57
2008	91.54	NE	91.54	25.03	13.09	54.87	-0.93	-0.52
2009	88.22	NE	88.22	24.15	12.41	53.00	-0.87	-0.48
2010	84.90	NE	84.90	23.26	11.74	51.13	-0.80	-0.43
2011	81.58	NE	81.58	22.38	11.07	49.26	-0.74	-0.38
2012	78.26	NE	78.26	21.50	10.39	47.38	-0.68	-0.34
2013	74.94	NE	74.94	20.61	9.72	45.51	-0.61	-0.29
2014	71.62	NE	71.62	19.73	9.04	43.64	-0.55	-0.24
Trend 1990-2014	-50.66%	NA	-50.66%	-70.70%	-53.38%	-28.23%	-61.72%	-74.60%
Trend 2013-2014	-4.43%	NA	-4.43%	-4.29%	-6.94%	-4.11%	-10.42%	-16.07%

### 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 6.1.3.3.

### 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)

##### a) Changes in carbon stock in biomass of land converted to settlements:

For the estimation of biomass stock and biomass growth in settlements, data from the municipality of Luxembourg were used. According to the magazine “EcoLogique n°1 2010”<sup>137</sup> 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<sup>138</sup>) 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

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<sup>137</sup> EcoLogique n°1, 2010, Ville de Luxembourg, p.6

<sup>138</sup> EcoLogique n°1, 2010, Ville de Luxembourg, p.11



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<sup>139</sup>. 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 6.2.4. 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 6.6.4.2 The area in conversion status from Forest Land to settlement for a time period of 20 years ranges from 1 770 ha to 1 037 ha between the years 1990 and 2014 causing annual emission rates due to the loss of biomass and C stock changes in soil and litter from 67.3 Gg CO<sub>2</sub> to 19.7 Gg CO<sub>2</sub>.

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:

$$\text{Annual change in carbon stock in biomass} = \Delta C_G + \Delta C_{\text{CONVERSION}} - \Delta C_L$$

$$\Delta C_{\text{CONVERSION}} = \sum_i \{ (B_{\text{AFTER}_i} - B_{\text{BEFORE}_i}) \cdot \Delta A_{\text{TO\_OTHERS}_i} \} \cdot CF$$

where:

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<sup>139</sup> DÖRFLINGER, A.; HIETZ, P.; MAIER, R.; PUNZ, W.; FUSSENEGGER, K. (1995): Ökosystem Großstadt Wien - Quantifizierung ökologischer Parameter unter besonderer Berücksichtigung der Vegetation; Bundesministerium für Wissenschaft und Forschung und MA 22. See also: Austria's National Inventory Report, Umweltbundesamt, REP-0265, Vienna, 2010, p.352.

$\Delta C_G$  = 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<sup>-1</sup>yr<sup>-1</sup> for perennial plants for a period of 20 years and 1.29 t C ha<sup>-1</sup>yr<sup>-1</sup> for annual plants for a period of 1 year).

$B_{AFTER(i)}$  = stocks on land type i immediately after conversion, tonnes d.m. ha<sup>-1</sup> (default value = 0).

$B_{BEFORE(i)}$  = stocks on land type i before conversion, tonnes d.m. ha<sup>-1</sup> (value for carbon stock before conversion is 6,4 t C ha<sup>-1</sup> for perennial cropland, 119,7 t C ha<sup>-1</sup> for forestland, 6,3 t C ha<sup>-1</sup> for grassland, 5,0 t C ha<sup>-1</sup> for annual cropland and 0,0 t C ha<sup>-1</sup> for wetland and 0,0 t C ha<sup>-1</sup> other land - see section 6.2.4.2.1 and **Table 6-18**).

$\Delta C_L$  = 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<sup>-1</sup> (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<sup>-1</sup>.

CF = carbon fraction of dry matter, tonne C (tonne d.m.)<sup>-1</sup>.

#### 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 :

$\Delta C_{DOM}$  = annual change in carbon stocks in dead wood or litter (tonnes C yr<sup>-1</sup>)

$C_o$  = dead wood/litter stock, under the old land-use category, tonnes C ha<sup>-1</sup> (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<sup>-1</sup> (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 (92 t C/ha). This resulted for total settlement in a soil C stock of 37 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 6.2.4.2.2, annual change in carbon stock of mineral soils = IEF(LUC<sub>i</sub>) \* conversion area, where :

$$IEF(LUC_{forestland \rightarrow settlements}) = - 3.393 \text{ t C/ha *yr}$$

$$IEF(LUC_{annual cropland \rightarrow settlements}) = - 1.609 \text{ t C/ha *yr}$$

$$IEF(LUC_{perennial cropland \rightarrow settlements}) = - 1.616 \text{ t C/ha *yr}$$

$$IEF(LUC_{grassland \rightarrow settlements}) = - 2.917 \text{ t C/ha *yr}$$

$$IEF(LUC_{\text{wetland} \rightarrow \text{settlements}}) = + 2.162 \text{ t C/ha *yr}$$

$$IEF(LUC_{\text{other land} \rightarrow \text{settlements}}) = + 2.162 \text{ t C/ha *yr}$$

EF(LUC<sub>j</sub>) = average yearly emission factor for carbon stock change in soil from land use change j

## 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 2014, 55 ha of Luxembourg were considered as other land (Figure 6-17). The area in conversion status from "Land converted to Other Land" for a time period of 20 years ranges from 56 ha to 17 ha between the years 1990 and 2014, causing annual emission rates due to C stock changes of biomass and soils from 1.6 Gg CO<sub>2</sub> to 0.3 Gg CO<sub>2</sub> (Table 6-28).

Annual LUCs to other land occur in the sub-categories "Forestland", "Cropland", "Grassland", "Settlements" and "Wetland".

Figure 6-17–Trend of wetland and LUC to Other Land (covering a conversion period of 20 years) from 1990-2014

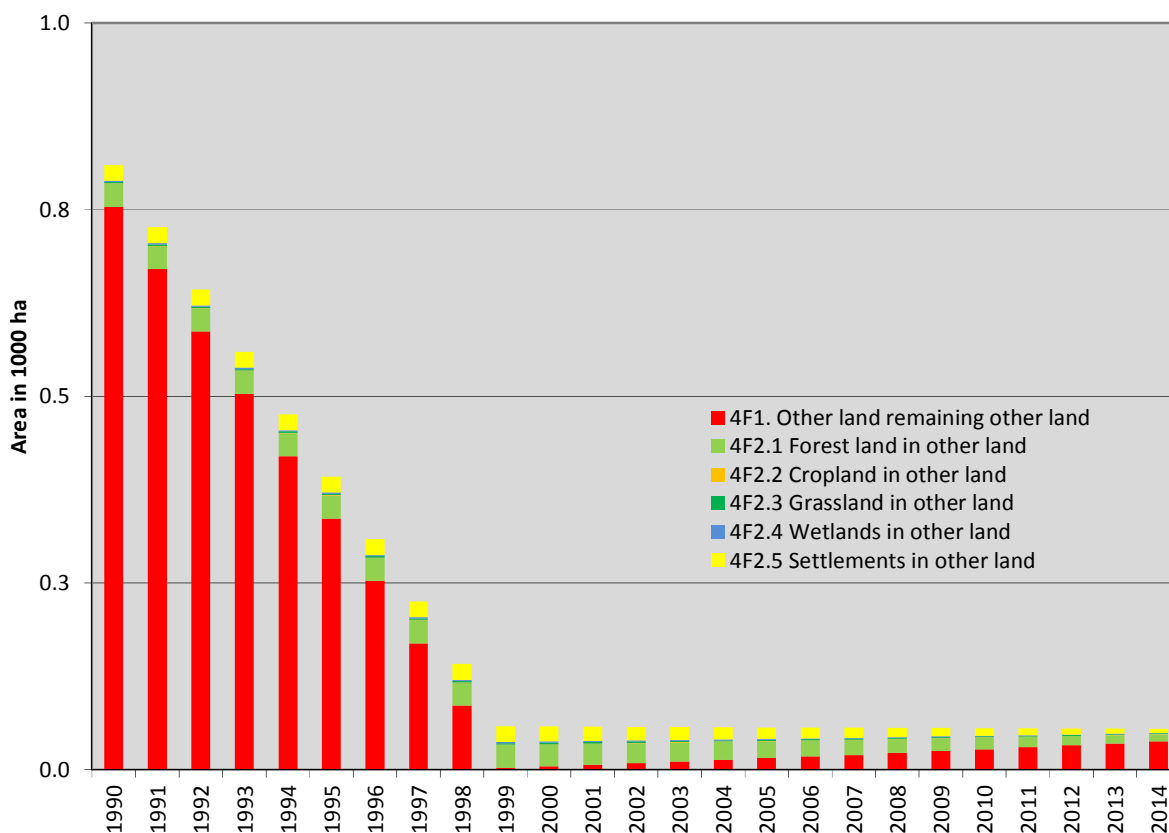


Table 6-28– CO<sub>2</sub> removals/emissions from IPCC category 4F – Other land from 1990-2014

4F - Other land								
Greenhouse gas emissions/removals (Gg CO <sub>2</sub> e)								
Year	4F Total Other land	4F1 OL remaining OL	4F2 Land converted to OL	4F2.1 Forestland converted to OL	4F2.2 Cropland converted to OL	4F2.3 Grassland converted to OL	4F2.4 Wetland converted to OL	4F2.5 Settlement converted to OL
1990	1.67	NE	1.67	1.44	0.01	0.04	0.00	0.19
1991	1.67	NE	1.67	1.44	0.01	0.04	0.00	0.19
1992	1.67	NE	1.67	1.44	0.01	0.04	0.00	0.19
1993	1.67	NE	1.67	1.44	0.01	0.04	0.00	0.19
1994	1.67	NE	1.67	1.44	0.01	0.04	0.00	0.19
1995	1.67	NE	1.67	1.44	0.01	0.04	0.00	0.19
1996	1.67	NE	1.67	1.44	0.01	0.04	0.00	0.19
1997	1.67	NE	1.67	1.44	0.01	0.04	0.00	0.19
1998	1.67	NE	1.67	1.44	0.01	0.04	0.00	0.19
1999	1.67	NE	1.67	1.44	0.01	0.04	0.00	0.19
2000	0.90	NE	0.90	0.70	0.01	0.03	0.00	0.16
2001	0.86	NE	0.86	0.67	0.01	0.03	0.00	0.15
2002	0.83	NE	0.83	0.64	0.01	0.03	0.00	0.15
2003	0.79	NE	0.79	0.61	0.01	0.03	0.00	0.14
2004	0.75	NE	0.75	0.58	0.01	0.03	0.00	0.13
2005	0.72	NE	0.72	0.56	0.01	0.03	0.00	0.12
2006	0.68	NE	0.68	0.53	0.01	0.03	0.00	0.11
2007	0.65	NE	0.65	0.50	0.01	0.03	0.00	0.11
2008	0.54	NE	0.54	0.41	0.01	0.03	0.00	0.10
2009	0.50	NE	0.50	0.38	0.01	0.03	0.00	0.09
2010	0.46	NE	0.46	0.35	0.00	0.02	0.00	0.08
2011	0.42	NE	0.42	0.32	0.00	0.02	0.00	0.07
2012	0.38	NE	0.38	0.29	0.00	0.02	0.00	0.06
2013	0.34	NE	0.34	0.26	0.00	0.02	0.00	0.05
2014	0.30	NE	0.30	0.23	0.00	0.02	0.00	0.05
Trend 1990-2014	-82.15%	NA	-82.15%	-83.97%	-52.47%	-52.06%	NA	-75.02%
Trend 2013-2014	-11.97%	NA	-11.97%	-11.51%	-8.97%	-8.94%	NA	-15.39%

### 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 6.1.3.3.

### 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:

$$\text{Annual change in carbon stock in biomass} = \Delta C_G + \Delta C_{\text{CONVERSION}} - \Delta C_L$$

$$\Delta C_{\text{CONVERSION}} = \sum_i \{ (B_{\text{AFTER}_i} - B_{\text{BEFORE}_i}) \cdot \Delta A_{\text{TO\_OTHERS}_i} \} \cdot CF$$

where :

$\Delta C_G$  = 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<sup>-1</sup>yr<sup>-1</sup>).

$B_{\text{AFTER}(i)}$  = stocks on land type i immediately after conversion, tonnes d.m. ha<sup>-1</sup> (default value = 0).

$B_{\text{BEFORE}(i)}$  = stocks on land type i before conversion, tonnes d.m. ha<sup>-1</sup> (value for carbon stock before conversion is 6,4 t C ha<sup>-1</sup> for perennial cropland, 119,7 t C ha<sup>-1</sup> for forestland, 6.3 t C ha<sup>-1</sup> for grassland, 4.3 t C ha<sup>-1</sup> for settlements, 5.0 t C ha<sup>-1</sup> for annual cropland and 0.0 t C ha<sup>-1</sup> other land - see section 6.2.4.2.1 and **Table 6-18**).

$\Delta C_L$  = 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<sup>-1</sup> (default value = 0).

$\Delta T_{\text{TO\_OTHERS}(i)}$  = area of land use i converted to another land-use category in a certain year, ha yr<sup>-1</sup>.

CF = carbon fraction of dry matter, tonne C (tonne d.m.)<sup>-1</sup>.

#### 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:

$$\Delta D_{\text{DOM}} = \frac{(C_n - C_o) \cdot A_{on}}{T_{on}}$$

where :

$\Delta C_{\text{DOM}}$  = annual change in carbon stocks in dead wood or litter (tonnes C yr<sup>-1</sup>)

$C_o$  = dead wood/litter stock, under the old land-use category, tonnes C ha<sup>-1</sup> (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<sup>-1</sup> (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 6.2.4.2.2, annual change in carbon stock of mineral soils =  $IEF(LUC_j)$  \* conversion area, where :

$$IEF(LUC_{forestland \rightarrow other\ land}) = - 5.554\ t\ C/ha\ *yr$$

$$IEF(LUC_{perennial\ cropland \rightarrow other\ land}) = - 3.778\ t\ C/ha\ *yr$$

$$IEF(LUC_{annual\ cropland \rightarrow other\ land}) = -3.770\ t\ C/ha\ *yr$$

$$IEF(LUC_{grassland \rightarrow other\ land}) = - 5.079\ t\ C/ha\ *yr$$

$$IEF(LUC_{settlements \rightarrow other\ land}) = - 2.162\ t\ C/ha\ *yr$$

$$IEF(LUC_{wetland \rightarrow other\ land}) = 0.0\ t\ C/ha\ *yr$$

$IEF(LUC_j)$  = average yearly emission factor for carbon stock change in soil from land use change j

## 6.8 Harvested Wood Products (4.G)

### 6.8.1 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.

### 6.8.2 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):

$$f_{IRW}(i) = \frac{IRW_P(i) - IRW_{EX}(i)}{IRW_P(i) + IRW_{IM}(i) - IRW_{EX}(i)} \quad \text{(Equation 6-1)}$$

**Figure 6-18 - Import, export and production of industrial roundwood in Luxembourg (origin: FAO and forest agency)**

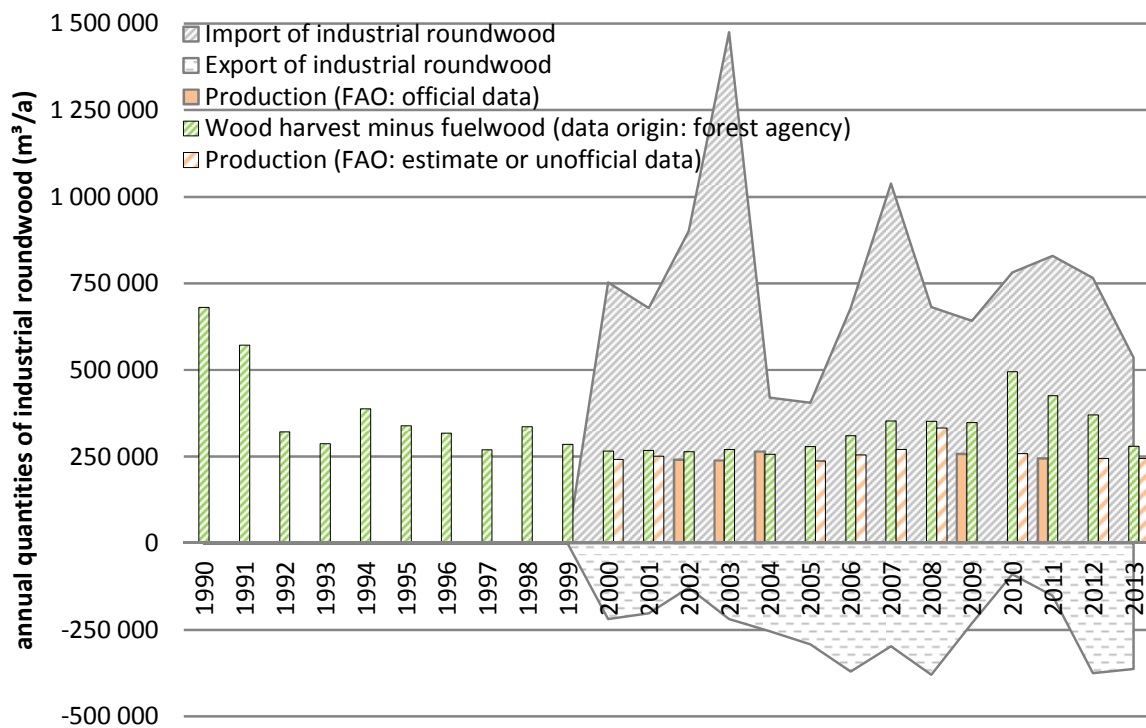


Figure 6-18 is showing data retrieved from the FAO database as well as data submitted by the forest agency (represented in green). In order to use the first order decay function described in the guidelines (Hirashi, et al., 2014) data for the main HWP categories need to date back, ideally, to 1960. For 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.

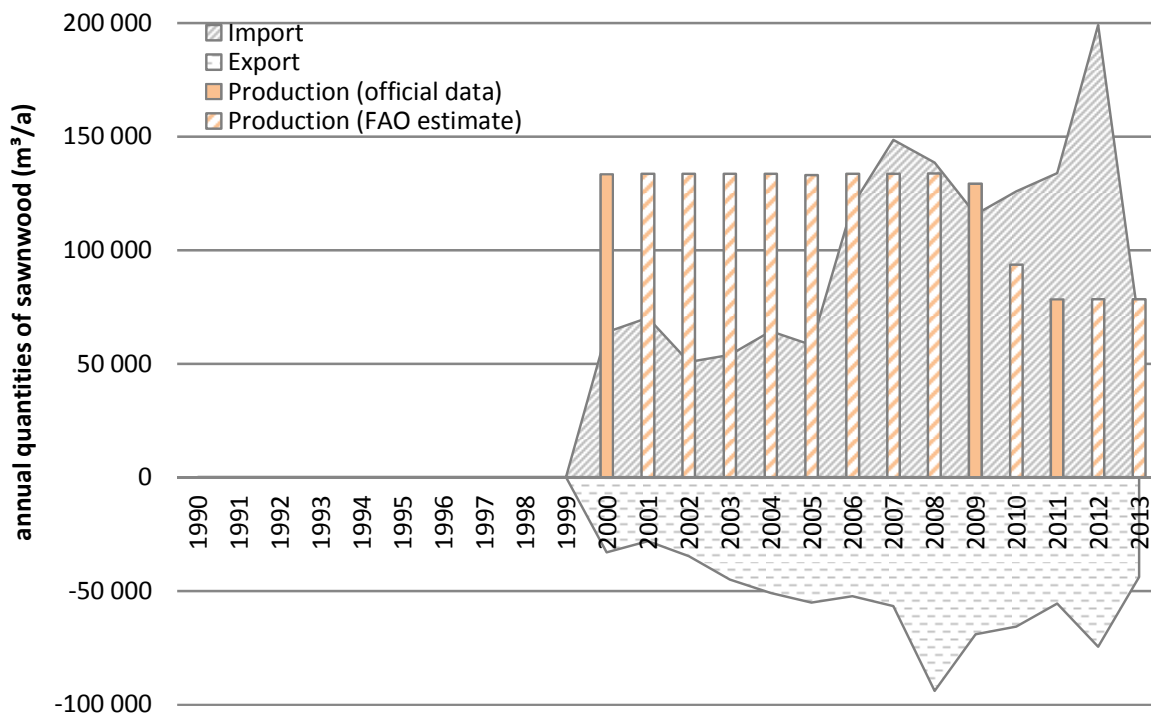
Alongside the data from the FAO database the quantity of wood harvested (minus fuelwood) is also shown in the same figure. This set of data seems more reliable as it shows the exact figure for wood removed in public forest (minus fuelwood) and an estimation of the wood removed in private forests (see section 6.2.4.1.1). 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 6-1). As a general trend 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. 
$$f_{IRW}(i) = \frac{IRW_P(i) - IRW_{EX}(i)}{IRW_P(i) + IRW_{IM}(i) - IRW_{EX}(i)}$$

### 6.8.3 Activity data: production, imports and exports of sawnwood

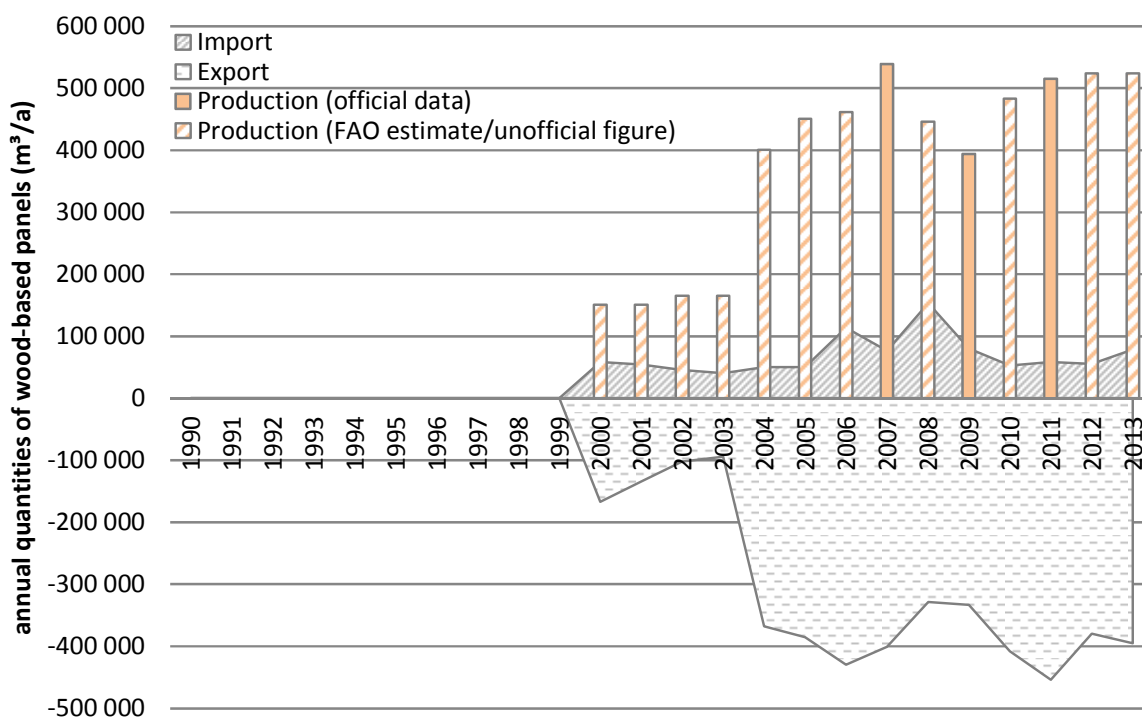
Figure 6-19 – import, export and production of sawnwood in Luxembourg (origin: FAO)



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 6-19 clearly highlight how unreliable the dataset for Luxembourg and questions whether the calculation on HWP can be based on this dataset.

#### 6.8.4 Activity data: production, imports and exports of wood-based panels

Figure 6-20 – 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 m³/a (Svehla & Winter, 2013)
- OSB (oriented strand board): 160.000 m³/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 6.8.2 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.

### 6.8.5 Activity data: production, imports and exports of wood pulp

Definition of wood pulp:

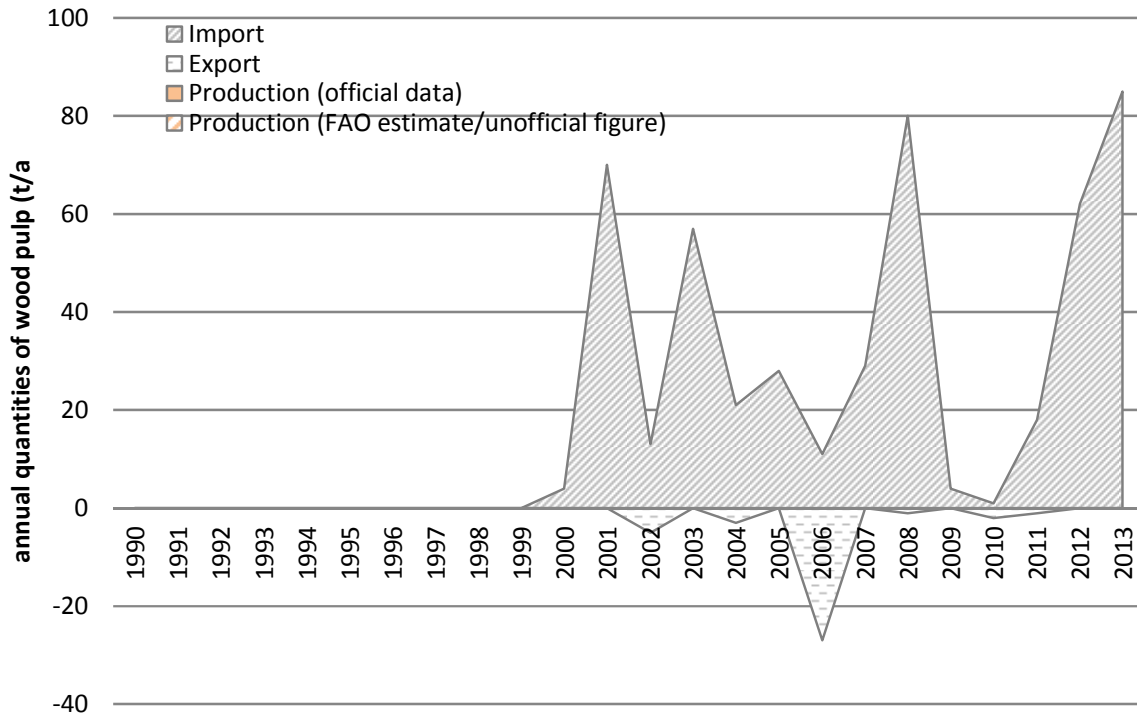
*“Fibrous material prepared from pulpwood, wood chips, particles, residues or recovered paper by mechanical and/or chemical process for further manufacture into paper, paperboard, fibreboard or other cellulose products. In the production and trade statistics, it represents the sum of: mechanical wood 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)

$$f_{PULP}(i) = \frac{PULP_P(i) - PULP_{EX}(i)}{PULP_P(i) + PULP_{IM}(i) - PULP_{EX}(i)} \quad (\text{Equation 6-2})$$

$f_{PULP}(i)$  = share of domestically produced wood pulp

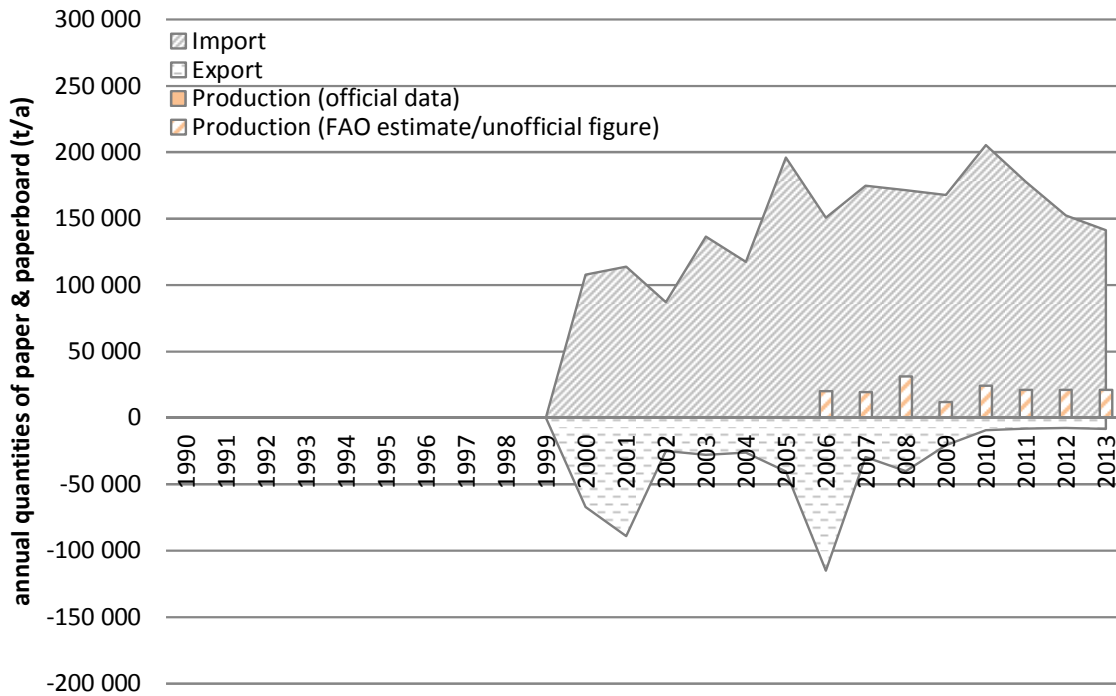
Figure 6-21 – import, export and production of wood pulp in Luxembourg (origin: FAO)



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.

#### 6.8.6 Activity data: production, imports and exports of paper and paperboard

Figure 6-22 – 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.

#### 6.8.7 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.**

## **6.9 Uncertainties and time-series consistency**

Please refer to Chapter 1.7 on the general uncertainty evaluation, and more specifically to sections 1.7.1.1.5 and 1.7.1.2.6 for uncertainties on the activity data, and emission factors.<sup>140</sup>

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<sup>140</sup> ARR 2012, §84.

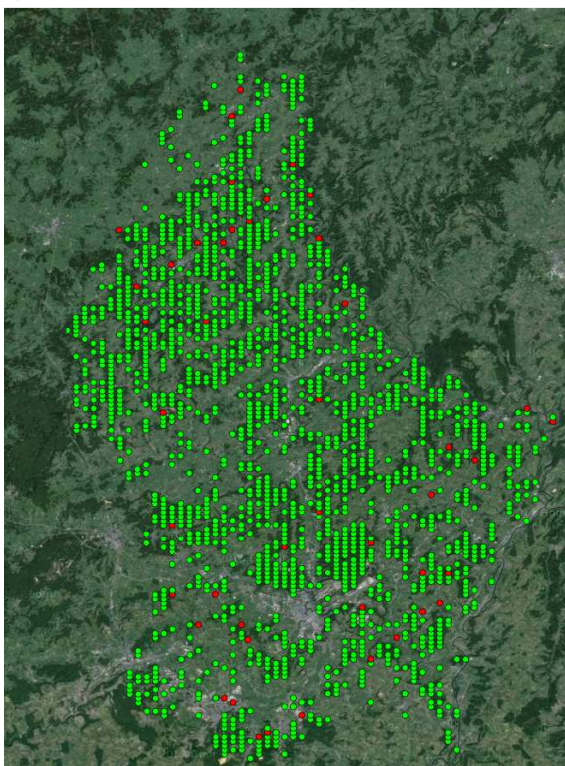
## 6.10 Category-specific QA/QC and verification

Processing of land use maps is verified as follows:

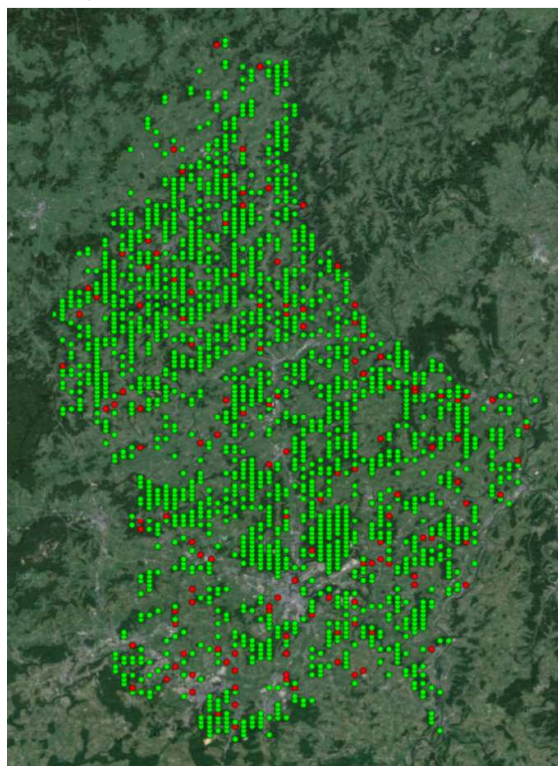
- ground reference is used, if necessary, for the differentiation of various species of trees (e.g. walnut and chestnut trees from other broad leaf trees) which might be difficult with the use of satellite images. However, the differentiation is relatively clear because, for example, plantations with walnuts or chestnuts do not occur in forest areas, or if they do occur next to forest areas, they are still spatially separated. Where doubts occur, and because of the small size of Luxembourg, some field inspections can easily be undertaken.
- 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 6-23 – Comparison of NFI grid definition points to LUC analysis**



Red points are areas defined as forest in the NFI but not in the LUC analysis (total: 45)



Red points are defined as forest in the in the LUC analysis 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



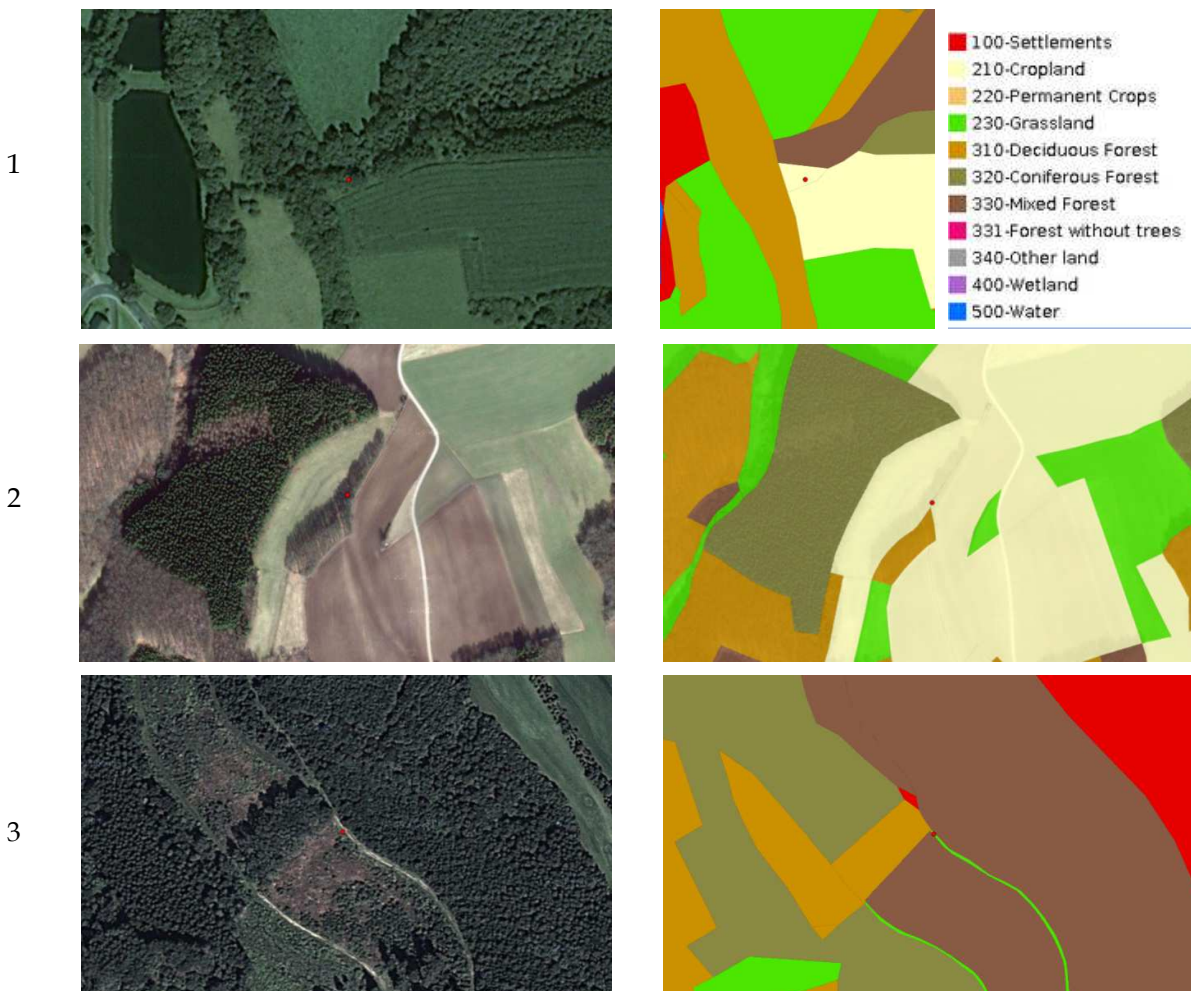
conducted via a GIS program. For this exercise the layer of grid points of the NFI have been put in comparison to the latest land use map from 2012.

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 6-23 the difference in numbers of red points is in line with the difference in total surface area ( $114-45 = 69 \rightarrow 3\,450$  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.

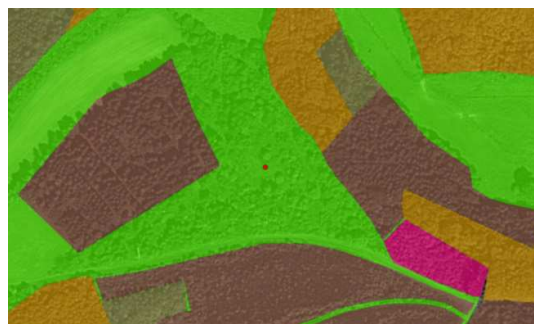
**Figure 6-24 – points defined as forest in NFI but not in LUC method**



4



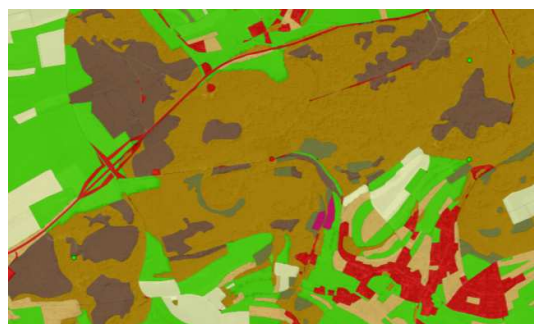
5



Pictures 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 6-25 – points defined as forest in LUC but not in NFI**

6



7

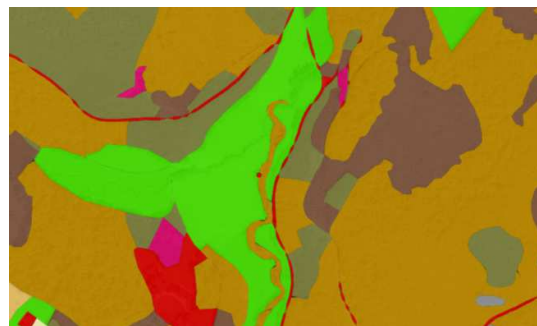




8



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 6-29 presents the main revisions and recalculations done since submission 2014v1.4 relevant to CRF Sector 4. For the quantitative aspect of these recalculations, please refer to Chapter 10.

**Table 6-29 – Changes in GHG inventories: submissions 2014v1.4 and 2016**

GHG source & sink category	Revisions 2014v1.4→ 2016v1	Type of revision
4 - LULUCF areas	Reporting of land use changes (>269 ha) between grassland and cropland in the category cropland remaining cropland	revised AD ARR 2014, §67
4 – LULUCF	The results of the second NFI have been included in order to establish EF for forest growth, dead wood, harvest rate and biomass carbon stock	Revised EF ARR 2014, §61, §61, §63, §64
4 – LULUCF	Calculation of a country specific EF for carbon stock on cropland remaining cropland	Revised EF ARR 2014, §69
4 – LULUCF	Recalculation of uncertainties in line with the results from the second NFI	Revision of uncertainties ARR 2014, §60
Transparency	Transparency was improved by providing more detailed explanations on methodologies and assumptions made.	improved Transparency ARR 2014, §58, §59, §65, §68, §71

#### 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 6-30 will be explored.

**Table 6-30 – 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)

### 7.1.1 Emission Trends

This Section briefly describes the emission trends from 1990 to 2014 for each of the IPCC Categories under CRF Sector 5. 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 sub-category 1A1a – *Fuel Combustion Activities – Energy Industries – Public Electricity and Heat Production*. Consequently, CRF Table 5C reports IE for this category (see Table 7-2).

As shown in Figure 7-1 and Table 7-1, that provide a quick overview on *Waste and Waste Water Treatment and Discharge* related emission trends between 1990 and 2014, and Figure 7-2 depicting the shares of each IPCC Category under CRF Sector 5 for both the years 1990 and 2014, total waste related GHG emissions have decreased by 48.13% from 1990 to 2014, and by 1.89% between 2013 and 2014. This evolution was mainly driven by the fact that, for IPCC Category 5A – *Solid Waste Disposal*, emissions have been reduced by 63.8% between 1990 and 2014 due to:

- 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 aerobic pre-treatment before landfilling;
- the recent installation of methane recovery systems at waste dumping sites.

For IPCC Category 5D – *Waste Water Treatment and Discharge*, emissions decreased by 29.38% in 2014 compared to the base year (1990), and by 0.78% compared to 2013. Waste water treatment plant (WWTP) capacities expressed in population-equivalents have steadily grown since 1990 (see Section 7.3.2). Indeed, WWTP capacities grew by some 80.24% (Table 7-14) over the period 1990 to 2014<sup>141</sup>, whereas nitrous oxide emissions, as shown in Table 7-1, decreased by 14.59%. Therefore, technical changes, with regard to waste water treatment, have an unquestionable role too, as the evolution of methane emissions (-47.31% from 1990 to 2014) confirms.

For category 5B – *Biological Treatment of Solid Waste*, unlike IPCC Category 5A, an increase of emissions is recorded for the years 1990 to 2014. With regard to compost production, this activity started on an “industrial scale” only in the early 1990s. This accelerated development, from 1993-2003<sup>142</sup> explains the very high, and therefore not really exploitable, percentage growths observed for both CH<sub>4</sub> and N<sub>2</sub>O.

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<sup>141</sup> This increase is notably explained by the significant population growth between 1990 and 2014, and by the increasing number of commuters who are crossing the border each working day (see Section 2.1.1.1 in Chapter 2). Percentage growths recorded for these two variables are, as well, largely above the one estimated for N<sub>2</sub>O emissions from WWTP.

<sup>142</sup> It stabilized since 2003 (see Section 7.5.2).

More details and explanations are also presented in the subsequent sections detailing each of the sector source categories.

**Figure 7-1 – GHG emission trends – indexes – for CRF Sector 5 – Waste: 1990-2014**

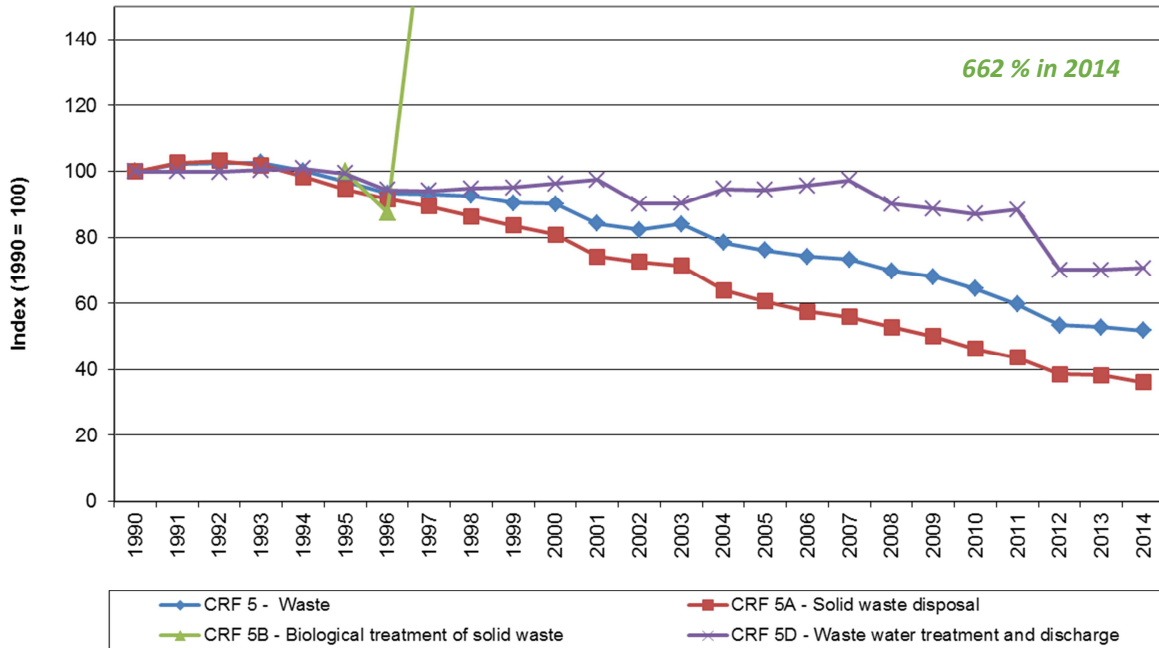
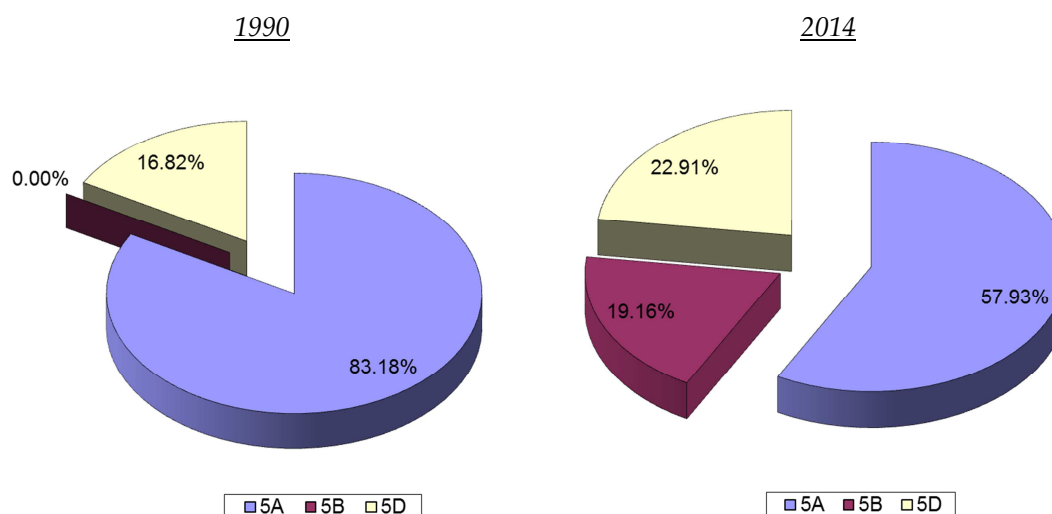


Table 7-1 - GHG emission trends in CO<sub>2</sub>e for CRF Sector 5 – Waste: 1990-2014CO<sub>2</sub> eq emissions (Gg) by source & sink category

Year	5A - Solid Waste Disposal				5B - Biological Treatment of Solid Waste				5C - Incineration and Open Burning of Waste				5D - Waste Water Treatment and Discharge				5E - Other				5 - Waste			
	Total	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Total	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Total	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Total	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Total	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Total	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
1990	79.92	NO	NE,NO	NA	0.00	NA	0.29	NE,NO	0.00	IE,NO	IE,NO	IE,NO	16.16	NO	0.29	0.03	0.00	NO	NO	NO	96.08	IE,NO	3.49	0.03
1991	81.95	NO	NE,NO	NA	0.00	NA	0.28	NE,NO	0.00	IE,NO	IE,NO	IE,NO	16.15	NO	0.28	0.03	0.00	NO	NO	NO	98.10	IE,NO	3.56	0.03
1992	82.41	NO	NE,NO	NA	0.00	NA	0.28	NE,NO	0.00	IE,NO	IE,NO	IE,NO	16.13	NO	0.28	0.03	0.00	NO	NO	NO	98.54	IE,NO	3.57	0.03
1993	81.37	NO	0.02	NA	1.00	NA	0.27	0.00	0.00	IE,NO	IE,NO	IE,NO	16.21	NO	0.27	0.03	0.00	NO	NO	NO	98.58	IE,NO	3.55	0.03
1994	78.64	NO	0.03	NA	1.16	NA	0.26	0.00	0.00	IE,NO	IE,NO	IE,NO	16.30	NO	0.26	0.03	0.00	NO	NO	NO	96.10	IE,NO	3.44	0.03
1995	75.71	NO	0.03	NA	1.44	NA	0.26	0.00	0.00	IE,NO	IE,NO	IE,NO	16.07	NO	0.26	0.03	0.00	NO	NO	NO	93.22	IE,NO	3.32	0.03
1996	73.21	NO	0.03	NA	1.26	NA	0.25	0.00	0.00	IE,NO	IE,NO	IE,NO	15.25	NO	0.25	0.03	0.00	NO	NO	NO	89.72	IE,NO	3.20	0.03
1997	71.49	NO	0.06	NA	2.76	NA	0.24	0.00	0.00	IE,NO	IE,NO	IE,NO	15.21	NO	0.24	0.03	0.00	NO	NO	NO	89.45	IE,NO	3.16	0.03
1998	69.08	NO	0.11	NA	4.58	NA	0.23	0.01	0.00	IE,NO	IE,NO	IE,NO	15.32	NO	0.23	0.03	0.00	NO	NO	NO	88.97	IE,NO	3.10	0.04
1999	66.83	NO	0.11	NA	4.76	NA	0.22	0.01	0.00	IE,NO	IE,NO	IE,NO	15.37	NO	0.22	0.03	0.00	NO	NO	NO	86.95	IE,NO	3.00	0.04
2000	64.63	NO	0.15	NA	6.38	NA	0.21	0.01	0.00	IE,NO	IE,NO	IE,NO	15.57	NO	0.21	0.03	0.00	NO	NO	NO	86.57	IE,NO	2.95	0.04
2001	59.23	NO	0.14	NA	5.85	NA	0.21	0.01	0.00	IE,NO	IE,NO	IE,NO	15.75	NO	0.21	0.04	0.00	NO	NO	NO	80.82	IE,NO	2.71	0.04
2002	57.94	NO	0.15	NA	6.59	NA	0.20	0.01	0.00	IE,NO	IE,NO	IE,NO	14.58	NO	0.20	0.03	0.00	NO	NO	NO	79.11	IE,NO	2.67	0.04
2003	57.05	NO	0.21	NA	9.14	NA	0.19	0.01	0.00	IE,NO	IE,NO	IE,NO	14.59	NO	0.19	0.03	0.00	NO	NO	NO	80.79	IE,NO	2.69	0.05
2004	51.10	NO	0.21	NA	8.87	NA	0.19	0.01	0.00	IE,NO	IE,NO	IE,NO	15.30	NO	0.19	0.04	0.00	NO	NO	NO	75.26	IE,NO	2.44	0.05
2005	48.41	NO	0.22	NA	9.40	NA	0.18	0.01	0.00	IE,NO	IE,NO	IE,NO	15.26	NO	0.18	0.04	0.00	NO	NO	NO	73.07	IE,NO	2.34	0.05
2006	45.94	NO	0.23	NA	9.82	NA	0.18	0.01	0.00	IE,NO	IE,NO	IE,NO	15.47	NO	0.18	0.04	0.00	NO	NO	NO	71.22	IE,NO	2.24	0.05
2007	44.67	NO	0.23	NA	9.98	NA	0.18	0.01	0.00	IE,NO	IE,NO	IE,NO	15.74	NO	0.18	0.04	0.00	NO	NO	NO	70.39	IE,NO	2.20	0.05
2008	42.22	NO	0.24	NA	10.23	NA	0.16	0.01	0.00	IE,NO	IE,NO	IE,NO	14.58	NO	0.16	0.04	0.00	NO	NO	NO	67.03	IE,NO	2.09	0.05
2009	40.01	NO	0.26	NA	10.95	NA	0.15	0.02	0.00	IE,NO	IE,NO	IE,NO	14.35	NO	0.15	0.04	0.00	NO	NO	NO	65.31	IE,NO	2.01	0.05
2010	37.05	NO	0.25	NA	10.67	NA	0.15	0.01	0.00	IE,NO	IE,NO	IE,NO	14.09	NO	0.15	0.03	0.00	NO	NO	NO	61.81	IE,NO	1.88	0.05
2011	34.91	NO	0.19	NA	8.20	NA	0.17	0.01	0.00	IE,NO	IE,NO	IE,NO	14.29	NO	0.17	0.03	0.00	NO	NO	NO	57.39	IE,NO	1.75	0.05
2012	30.80	NO	0.22	NA	9.28	NA	0.16	0.01	0.00	IE,NO	IE,NO	IE,NO	11.31	NO	0.16	0.02	0.00	NO	NO	NO	51.40	IE,NO	1.61	0.04
2013	30.53	NO	0.21	NA	8.94	NA	0.16	0.01	0.00	IE,NO	IE,NO	IE,NO	11.33	NO	0.16	0.02	0.00	NO	NO	NO	50.79	IE,NO	1.59	0.04
2014	28.87	NO	0.22	NA	9.55	NA	0.15	0.01	0.00	IE,NO	NO,IE	NO,IE	11.41	NO	0.15	0.03	0.00	NO	NO	NO	49.83	IE,NO	1.53	0.04
<i>Trend</i>																								
1990-2014	-63.88%	NA	NA	NA	NA	NA	-47.31%	NA	NA	NA	NA	NA	-29.38%	NA	-47.31%	-14.59%	NA	NA	NA	NA	-48.13%	NA	-56.11%	30.35%
<i>Trend</i>																								
2013-2014	-5.44%	NA	6.85%	NA	6.85%	NA	-2.13%	6.85%	NA	NA	NA	NA	0.78%	NA	-2.13%	2.32%	NA	NA	NA	NA	-1.89%	NA	-3.50%	3.84%

Notes: CH<sub>4</sub> emissions are converted in CO<sub>2</sub>e 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<sub>2</sub>O emissions are converted in CO<sub>2</sub>e 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 7-2 – IPCC Categories weights for CRF Sector 5 – Waste: 1990 and 2014**



## 7.2 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 2014.

Emissions from this sector comprise emissions for the main three categories: *Solid Waste Disposal* (5A), *Biological Treatment of Solid Waste* (5B) and *Waste Water Treatment and Discharge* (5D). For more details on categories, where emissions are not occurring and categories that are not estimated or included elsewhere (see Table 7-2).

*Incineration and Open Burning of Waste* (5C) related GHG emissions are allocated to IPCC Sub-category 1A1a – *Fuel Combustion Activities – Energy Industries – Public Electricity and Heat Production* (see Section 3.2.4) since energy is recovered and injected in the public electricity network from waste burned in the sole incinerator of the country.

### 7.2.1 Completeness

Table 7-2 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 7-2 - Overview of subcategories of CRF Sector 5 – Waste: status of emission estimates for CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O**

GHG source & sink category	Description	Status		
		CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
5A1	Solid waste disposal on land – managed waste disposal on land	NO	X	

GHG source & sink category	Description	Status		
		CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
5A2	Solid waste disposal on land – unmanaged waste disposal sites	NO	NO	
5A3	Solid waste disposal on land - other	NA	NA	
5B	Biological Treatment of Solid Waste	NO	NO (1990-1992)	5B
5C	Waste incineration	IE *	IE *	IE *
5D1	Waste water handling – industrial waste water		NA	X
5D2	Waste water handling – domestic & commercial waste water		X	X
5D3	Waste water handling – other		NA	NA

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

\* = waste incineration is recorded under CRF Sub-category 1A1a since electricity is produced from incinerated municipal waste residues.

## 7.3 Solid Waste Disposal (5A)

### 7.3.1 Source Category Description

This section describes GHG emissions resulting from solid waste disposal on land, which, in Luxembourg, only originate from managed waste disposal sites. There are no unmanaged waste disposal sites. Hence, emissions from IPCC Category 5A – *Solid Waste Disposal* are equal to the one deriving from IPCC Sub-category 5A1 – *Managed Waste Disposal Sites*.

In 2014, this source category was responsible for 57.9% of waste treatment methane related emissions – excluding waste incineration – and for 5.06% of the total methane emissions estimated for Luxembourg (12.89% in 1990). It represented 0.01% of the total GHG emissions (excluding LULUCF) (0.02% in 1990). The emissions, from the closed landfill site for industrial waste according to data from the annual analysis reports since 2000, have been included in this category. Neither CO<sub>2</sub>, nor N<sub>2</sub>O emissions are occurring in this category. Table 7-3 details methane emissions, generated by each of the solid waste disposal sites, as well as the implied emission factor.

The source category 5A1 – *Managed Waste Disposal Sites* has been identified as a key category for CH<sub>4</sub> for the period 1990-2003 (level assessment excluding LULUCF).



**Table 7-3 - CH<sub>4</sub> emissions from 5A1 - Managed Waste Disposal Sites (1990-2014)**

5A - Solid Waste Disposal on Land								
	MSW deposited	CH <sub>4</sub> - Emissions				CH <sub>4</sub> - Recovery		
Year	Total Gg	Total Gg	SIDEC, SIGRE, SIDA tonnes	Ronnebier g tonnes	IEF kg/t MSW	Total Gg	SIDEC, SIGRE, SIDA tonnes	Ronnebier g tonnes
1990	87.24	3.197	3 197	NE	36.478	NO	0.000	NO
1991	73.76	3.278	3 278	NE	43.976	NO	0.000	NO
1992	52.91	3.296	3 296	NE	61.414	NO	0.000	NO
1993	42.74	3.255	3 255	NE	49.292	NO	0.000	NO
1994	41.72	3.146	3 146	NE	49.093	NO	0.000	NO
1995	44.30	3.028	3 028	NE	44.101	NO	0.000	NO
1996	61.82	2.929	2 929	NE	31.134	NO	0.000	NO
1997	49.71	2.860	2 860	NE	37.126	NO	0.000	NO
1998	48.77	2.763	2 763	NE	36.483	NO	0.000	NO
1999	43.36	2.673	2 673	NE	39.826	NO	0.000	NO
2000	39.89	2.659	2 585	74	43.080	NO	0.000	NO
2001	41.60	2.428	2 369	59	37.292	0.153	152.711	NO
2002	42.22	2.362	2 318	44	35.811	0.135	135.013	NO
2003	43.56	2.315	2 282	33	34.386	0.102	101.636	NO
2004	37.13	2.074	2 044	30	34.887	0.302	302.381	NO
2005	46.13	1.967	1 936	31	26.877	0.312	311.705	NO
2006	40.84	1.868	1 837	31	28.949	0.344	344.385	NO
2007	32.59	1.806	1 787	19	34.553	0.321	321.321	NO
2008	32.09	1.701	1 689	12	32.821	0.308	307.765	NO
2009	29.27	1.609	1 600	8	33.438	0.271	270.525	NO
2010	29.78	1.490	1 482	8	26.775	0.277	277.395	NO
2011	30.36	1.405	1 396	8	31.132	0.261	261.467	NO
2012	31.14	1.238	1 232	6	26.597	0.344	344.110	NO
2013	31.85	1.228	1 221	6	27.052	0.267	266.863	NO
2014	32.60	1.161	1 155	7	25.817	0.260	260.274	NO
<b>Trend 1990-2014</b>	-62.63%	-63.67%	-63.88%	NA	-29.23%	NA	NA	NA
<b>Trend 2013-2014</b>	2.36%	-5.40%	-5.44%	2.44%	-4.57%	-2.47%	-2.47%	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.

### 7.3.2 Methodological Issues

#### 7.3.2.1 Luxembourg's Waste Collection System

IPCC Category 5A covers waste disposal on land – or landfilled waste – whether generated by households or enterprises. Luxembourg's GHG inventory covers all waste disposals on land. Municipal waste consists of waste collected from households as well as refuses similar to households waste generated by small industrial enterprises, retail shops and services (private or institutional). In other words, municipal waste corresponds to the totality of waste collected by municipalities.<sup>143</sup>

<sup>143</sup> For details on municipal waste collection, see:

Municipal waste is partly landfilled (*i.e.* solid waste to be accounted for under IPCC Category 5A), partly incinerated (*i.e.* solid waste to be accounted for under IPCC Category 1A1a as energy is recovered from incineration) and partly recycled or recovered. For the latter, door-to-door collections of selected refuses (paper and cardboard, packaging (plastic bottles, cans & Tetra-Pak®), garden waste, *etc.*), recycling centres and/or on-street specific waste containers where selected waste can be deposited, exist.

In Luxembourg, the collection of municipal waste falls within the competence of municipalities which joined to municipal waste management associations. These associations are:

- SIDEC<sup>144</sup> = association for the management of household and similar to household waste for the municipalities of the regions Diekirch, Ettelbruck and Colmar-Berg;
- SIDOR<sup>145</sup> = association for the management of household and similar to household waste for the municipalities of the districts Luxembourg, Esch-sur-Alzette and Capellen;
- SIGRE<sup>146</sup> = association for the management of household and similar to household waste for the municipalities of the regions Grevenmacher, Remich and Echternach;
- SIDA<sup>147</sup> = association for the management of household and similar to household waste for the municipalities of the region Wiltz and other regions of the north of the country.

All these associations 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. Hence, nowadays, there are 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. As underlined above, the activities and emissions related to the SIDOR incinerator are dealt with under IPCC Sub-category 1A1a – *Public Electricity and Heat Production*.

At the SIGRE site, a methane recovery system is operated since 2000, and, since 2002, at the SIDEC site. The aerobic pre-treatment in heaps at SIGRE is made since 1993. The biological treatment in tunnels at SIDEC is fully operational since 2007.

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[http://www.environnement.public.lu/dechets/statistiques\\_indicateurs/LUXUS\\_Daten/index.html](http://www.environnement.public.lu/dechets/statistiques_indicateurs/LUXUS_Daten/index.html) (in German)

[http://www.environnement.public.lu/dechets/statistiques\\_indicateurs/index.html](http://www.environnement.public.lu/dechets/statistiques_indicateurs/index.html), line “*Activité des parcs à conteneurs (recycling centres)*” (in French).

<sup>144</sup> Syndicat Intercommunal pour la gestion des Déchets from households en provenance des ménages et des déchets assimilables des communes de la région de Diekirch, Ettelbruck et Colmar-Berg.

<sup>145</sup> Syndicat Intercommunal pour la gestion des déchets en provenance des ménages et des déchets assimilables des communes des cantons de Luxembourg, d'Esch-sur-Alzette et de Capellen.

<sup>146</sup> Syndicat Intercommunal pour la collecte, l'évacuation et l'élimination des ordures provenant des communes de la région de Grevenmacher, Remich et Echternach.

<sup>147</sup> Syndicat de Communes pour la collecte, l'évacuation et l'élimination des ordures provenant des communes de la région de Wiltz et du nord du pays.

Before these managed waste dumping sites were installed, the waste was dumped to local unmanaged dumping sites within the municipalities. The controlled landfill of SIDEC opened in 1972, the landfill of SIGRE in 1979.

Table 7-4 summarizes the situation for each waste management association.

**Table 7-4 – Municipal solid waste management in Luxembourg**

Association	Waste elimination scheme	Operating years with regard to the GHG inventory
SIDEC	landfill	1972-2014
SIDOR	incineration	1976-2014
SIGRE	landfill	1979-2014
SIDA	landfill	till 1993

Source: Environment Agency.

To summarize:

- IPCC Category 5A covers methane emissions from waste disposal on land. No CO<sub>2</sub> emissions derived from non-biological or inorganic waste sources have been identified so far;
- Only managed waste disposal on land is relevant for Luxembourg. There are no unmanaged or other waste disposal sites any more (→ IPCC Category 5A = IPCC Sub-category 5A1);
- Municipal waste from households or similar to households waste are accounted for in the inventory. The emissions of the closed industrial waste disposal on land site (Ronnebiert) are estimated for the period 2000 to 2014.<sup>148</sup>

### 7.3.2.2 Data Origin

Waste disposal is organized *via* three regional disposal districts, which originally have been formed due to hygienic considerations (see also Section 7.3.2.1). The southern district (SIDOR) operates a waste incinerator (MWI), which is considered in the “energy” section. About two thirds of Luxembourg’s waste is being combusted, approx. 130000 t/yr. Recently, the northern district (SIDEC) started a mechanical-biological treatment plant. Routinely separation of combustible material has been performed, which is used at the only waste incinerator. The remaining waste is landfilled, like also in the eastern district (SIGRE) where only simple (cold) pre-treatment is performed. Recovery of landfill gas started in 2002 (flaring) and 2000 (electricity and heat plant), respectively.

Amounts of waste have originally been estimated by volume only, but since the 1990’s waste is systematically weighted. Waste fractions have been analysed in specific campaigns (mid-1990’s,

<sup>148</sup> Today, there are no landfill sites for purely industrial waste in Luxembourg. However, one site existed in the past and it has been closed down in the early 1990s (Ronnebiert site).

mid-2000's, 2009/2010 and around 2000 and 2009 for SIDOR only), specifically clustering information by consumer habits and availability of waste separation facilities.

Waste analysis is being used to determine IPCC waste fractions to which default DOC contents are applied. The composition of the combustible fraction taken off the SÍDEC waste and delivered to the MWI was analysed in 2009. This fraction, having a higher C content than the average waste, was taken into account for the calculation at the MWI.

Recovered CH<sub>4</sub>, as determined from monthly reports of the landfill operators (measured quantities) is subtracted from the estimated emissions.

#### **7.3.2.3 Methodology**

The spreadsheet implementing the Tier 1 methodology from the 2006 IPCC Guidelines for national greenhouse gas inventories has been used. Following the recommendations of the In-Country Review of 2008 and the centralized review of 2009<sup>149</sup>, the calculation was made since 1950 and also taking into account the pre-treatment of waste before landfilling. In 2009, the Environment Agency conducted two studies:

- 1) Composition of the high caloric fraction from SÍDEC, and
- 2) Emissions of the waste deposited at the MSW landfills.

In 2011, the study "Emissions of the waste deposited at the MSW landfills" was refined for the period 2004-2007, calculated for the years 2008 and 2010 and extrapolated for the years 2010 to 2014.

#### **7.3.2.4 Parameters**

Table 7-5 gives an overview of the parameters used for the estimation of emissions from solid waste disposal on land. Only default values were used as no country specific values are available, except for the methane oxidation factor.

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<sup>149</sup> ARR 2009, § 106.

Table 7-5 – Parameters used for the calculation of emissions from CRF category 5A

	IPCC default value		Country-specific parameters	
			Value	Reference and remarks
Starting year		1950	1950	
DOC (Degradable organic carbon) (weight fraction, wet basis)	Waste by composition ▼			
	Range	Default		
Food waste	0.08-0.20	0.15	0.15	
Garden	0.18-0.22	0.2	0.2	
Paper	0.36-0.45	0.4	0.4	
Wood and straw	0.39-0.46	0.43	0.43	
Textiles	0.20-0.40	0.24	0.24	
Disposable nappies	0.18-0.32	0.24	0.24	
Sewage sludge	0.04-0.05	0.05	0.05	
Industrial waste	0-0.54	0.15	0.15	
DOCf (fraction of DOC dissimilated)		0.5	0.5	
Methane generation rate constant (k) (years <sup>-1</sup> )	Wet temperate ▼			
	Range	Default		
Food waste	0.1–0.2	0.185	0.185	
Garden	0.06–0.1	0.1	0.1	
Paper	0.05–0.07	0.06	0.06	
Wood and straw	0.02–0.04	0.03	0.03	
Textiles	0.05–0.07	0.06	0.06	
Disposable nappies	0.06–0.1	0.1	0.1	
Sewage sludge	0.1–0.2	0.185	0.185	
Industrial waste	0.08–0.1	0.09	0.09	
Delay time (months)		6	6	
Fraction of methane (F) in developed gas		0.5	0.5	
Conversion factor, C to CH <sub>4</sub>		1.33	1.33	
Oxidation factor (OX)		0	0.1	
Parameters for carbon storage				
% paper in industrial waste		0%	0%	
% wood in industrial waste		0%	0%	

Note: If parameters shown in column "country specific values" are identical to the IPCC default values, this means that the IPCC default value was used.

### 7.3.2.5 Methane Correction Factor (MCF)

From 1950 to 1971, 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. In 1972, the controlled landfill of SIDEDEC was installed and more and more municipalities joined the SIDEDEC. In 1979, the controlled landfill of SIGRE was installed and more and more municipalities joined the SIGRE. These two landfills had an impact in time on the MCF. In 1993, SIGRE started with a cold pre-treatment of waste under aerobic conditions. Since 2007, the mechano-biological pre-treatment at SIDEDEC is fully operational. 100% of municipal and bulky waste is since then pre-treated before landfilling. Since then the MCF of 0.1 for managed, uncategorised landfills is applicable. This value is endorsed in the 2006 IPCC Guidelines, which specified under the mechanical-biological (MB) treatment of waste that due to the reduced amount

in material, organic content and biological activity, the MB-treated waste will produce up to 95 per cent less CH<sub>4</sub> than untreated waste when disposed in SWDS<sup>150</sup>. For an overview of the evolution, see Table 7-6.

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<sup>150</sup> ARR2012 § 103.

**Table 7-6 – Methane correction factors and waste distribution by waste management type**

	MSW					
	Un- managed, shallow MCF	Un- managed, deep MCF	Managed			Distri-bution Check
			Anaerobic MCF	Semi- aerobic MCF	Mecanical Biological Treatment MCF	
IPCC default	0.4	0.8	1	0.5	0.6	
Country-specific value	0.4	0.8	1	0.5	0.1	
	Distribution of Waste by Waste Management Type					
"Fixed" Country- specific value	25%	30%	25%	5%	15%	Total (100%)
Year	%	%	%	%	%	
1950	50%	50%	0%	0%	0%	100%
1951	50%	50%	0%	0%	0%	100%
1952	50%	50%	0%	0%	0%	100%
1953	50%	50%	0%	0%	0%	100%
1954	50%	50%	0%	0%	0%	100%
1955	50%	50%	0%	0%	0%	100%
1956	50%	50%	0%	0%	0%	100%
1957	50%	50%	0%	0%	0%	100%
1958	50%	50%	0%	0%	0%	100%
1959	50%	50%	0%	0%	0%	100%
1960	50%	50%	0%	0%	0%	100%
1961	50%	50%	0%	0%	0%	100%
1962	50%	50%	0%	0%	0%	100%
1963	50%	50%	0%	0%	0%	100%
1964	50%	50%	0%	0%	0%	100%
1965	50%	50%	0%	0%	0%	100%
1966	50%	50%	0%	0%	0%	100%
1967	50%	50%	0%	0%	0%	100%
1968	50%	50%	0%	0%	0%	100%
1969	50%	50%	0%	0%	0%	100%
1970	50%	50%	0%	0%	0%	100%
1971	50%	50%	0%	0%	0%	100%
1972	45%	45%	10%	0%	0%	100%
1973	40%	40%	20%	0%	0%	100%
1974	40%	40%	20%	0%	0%	100%
1975	40%	40%	20%	0%	0%	100%
1976	40%	40%	20%	0%	0%	100%
1977	40%	40%	20%	0%	0%	100%
1978	40%	40%	20%	0%	0%	100%
1979	10%	10%	80%	0%	0%	100%
1980	10%	10%	80%	0%	0%	100%
1981	10%	10%	80%	0%	0%	100%
1982	10%	10%	80%	0%	0%	100%
1983	10%	10%	80%	0%	0%	100%
1984	10%	10%	80%	0%	0%	100%
1985	10%	10%	80%	0%	0%	100%
1986	10%	10%	80%	0%	0%	100%
1987	10%	10%	80%	0%	0%	100%
1988	10%	10%	80%	0%	0%	100%
1989	10%	10%	80%	0%	0%	100%
1990	10%	10%	80%	0%	0%	100%
1991	10%	10%	80%	0%	0%	100%
1992	10%	10%	80%	0%	0%	100%
1993	0%	0%	79%	0%	21%	100%
1994	0%	0%	71%	0%	29%	100%
1995	0%	0%	69%	0%	31%	100%
1996	0%	0%	54%	0%	46%	100%
1997	0%	0%	55%	0%	45%	100%
1998	0%	0%	55%	0%	45%	100%
1999	0%	0%	60%	0%	40%	100%
2000	0%	0%	67%	0%	33%	100%
2001	0%	0%	66%	0%	34%	100%
2002	0%	0%	63%	0%	37%	100%
2003	0%	0%	62%	0%	38%	100%
2004	0%	0%	58%	0%	42%	100%
2005	0%	0%	56%	0%	44%	100%
2006	0%	0%	53%	0%	47%	100%
2007	0%	0%	39%	0%	61%	100%
2008	0%	0%	17%	0%	83%	100%
2009	0%	0%	15%	0%	85%	100%
2010	0%	0%	15%	0%	85%	100%
2011	0%	0%	15%	0%	85%	100%
2012	0%	0%	15%	0%	85%	100%
2013	0%	0%	15%	0%	85%	100%
2014	0%	0%	15%	0%	85%	100%

Note: If parameters shown as "country specific values" are identical to the IPCC default values, this means that the IPCC default value was used.

### **7.3.2.6 Activity Data**

Activity data were calculated in accordance to the MSW produced per capita/year. Data on the population are from STATEC.

No national data on municipal waste production from 1950 to 1989 were available. Data from Germany for the years 1950 and 1975 were used. Data in-between were interpolated. Data for Luxembourg for the year 1990 were available (581 kg) which were nearly identical to the IPPC default values (560 kg). Data up to the year 2014 were from the Environment Agency taking into account the effect of aerobic decomposition at SIGRE since 1993 and at SIDEC since 2007.

Municipal waste was completely landfilled till 1975. In 1976 the incinerator of SIDOR opened and waste incinerated was subtracted in accordance of the population living in the SIDOR municipalities. Data from 1990 to 2014 were data from the Environment Protection Agency taking into account the effect of aerobic decomposition.

Waste composition is exactly known since 1992. The data from the national waste composition analyse 1992/94 were used till 2003. For the years 2004 to 2009 the data from the 2011 study were used taking into account the aerobic pre-treatment before landfilling. For 2010-2014 values of the composition of the waste are as of 2009. For the years before 1992 no data was available. Luxembourg oriented its values near the IPPC default values but some changes were made: 1950-1974 it is assumed that the fractions “food”, “paper” and “wood” landfilled were lower. The difference was allocated to the fraction “plastics, other inert” waste.

Adaptations for the fraction “food” were made for 1975-1991 in accordance to the IPPC default values. One-way nappies appeared in the 1970 and were allocated to the waste composition.

An overview of the waste composition trends is given in Table 7-7.



Table 7-7– Waste composition (1990-2014)

Year	Population millions	Waste per capita kg/cap/yr	Total MSW Gg	% to SWDS	Composition of waste going to solid waste disposal sites							Total (=100%)
					Food	Garden	Paper	Wood	Textile	Nappies	Plastics, other inert	
				%	%	%	%	%	%	%	%	
1960	0.312	300	93.6000	100%	20%	0%	25%	5%	0%	0%	50%	100%
1961	0.315	305	96.0411	100%	20%	0%	25%	5%	0%	0%	50%	100%
1962	0.318	310	98.5800	100%	20%	0%	25%	5%	0%	0%	50%	100%
1963	0.321	315	101.1150	100%	20%	0%	25%	5%	0%	0%	50%	100%
1964	0.324	320	103.6800	100%	20%	0%	25%	5%	0%	0%	50%	100%
1965	0.327	330	107.9100	100%	20%	0%	25%	5%	0%	0%	50%	100%
1966	0.331	335	110.8850	100%	20%	0%	25%	5%	0%	0%	50%	100%
1967	0.335	340	113.8286	100%	20%	0%	25%	5%	0%	0%	50%	100%
1968	0.335	350	117.2500	100%	20%	0%	25%	5%	0%	0%	50%	100%
1969	0.336	355	119.2800	100%	20%	0%	25%	5%	0%	0%	50%	100%
1970	0.338	360	121.6800	100%	20%	0%	25%	5%	0%	0%	50%	100%
1971	0.340	365	124.0420	100%	20%	0%	25%	5%	0%	0%	50%	100%
1972	0.344	370	127.2800	100%	20%	0%	25%	5%	0%	0%	50%	100%
1973	0.346	375	129.7500	100%	20%	0%	25%	5%	0%	0%	50%	100%
1974	0.353	380	132.2400	100%	20%	0%	25%	5%	0%	0%	50%	100%
1975	0.357	385	134.3650	100%	24%	1%	25%	11%	1%	1%	37%	100%
1976	0.361	395	138.6450	40%	24%	1%	25%	11%	1%	1%	37%	100%
1977	0.361	405	143.3700	40%	24%	1%	25%	11%	1%	1%	37%	100%
1978	0.362	415	148.5700	40%	24%	1%	25%	11%	1%	1%	37%	100%
1979	0.362	420	151.6200	40%	24%	1%	25%	11%	1%	1%	37%	100%
1980	0.364	440	159.7200	40%	24%	1%	25%	11%	1%	1%	37%	100%
1981	0.365	460	167.4400	40%	24%	1%	24%	11%	1%	2%	37%	100%
1982	0.366	480	175.6800	40%	24%	1%	24%	11%	1%	2%	37%	100%
1983	0.365	495	182.1600	40%	24%	1%	24%	11%	1%	2%	37%	100%
1984	0.366	510	188.1900	40%	24%	1%	24%	11%	1%	2%	37%	100%
1985	0.366	520	192.9200	40%	29%	4%	20%	11%	1%	2%	33%	100%
1986	0.367	530	197.1600	40%	29%	4%	20%	11%	1%	2%	33%	100%
1987	0.369	550	205.1500	40%	29%	4%	20%	11%	1%	2%	33%	100%
1988	0.372	560	212.2400	40%	29%	4%	20%	11%	1%	2%	33%	100%
1989	0.376	570	218.3100	40%	29%	4%	20%	11%	1%	2%	33%	100%
1990	0.379	581	223.6850	39%	29%	4%	20%	11%	1%	2%	33%	100%
1991	0.384	562	216.9320	34%	29%	4%	20%	11%	1%	2%	33%	100%
1992	0.390	503	195.9688	27%	39%	8%	16%	1%	1%	5%	30%	100%
1993	0.395	451	178.0716	24%	39%	8%	16%	1%	1%	5%	30%	100%
1994	0.400	434	173.8257	24%	39%	8%	16%	1%	1%	5%	30%	100%
1995	0.406	420	170.3855	26%	39%	8%	16%	1%	1%	5%	30%	100%
1996	0.412	385	158.5226	39%	39%	8%	16%	1%	1%	5%	30%	100%
1997	0.417	397	165.6969	30%	39%	8%	16%	1%	1%	5%	30%	100%
1998	0.422	385	162.5595	30%	39%	8%	16%	1%	1%	5%	30%	100%
1999	0.427	406	173.4377	25%	39%	8%	16%	1%	1%	5%	30%	100%
2000	0.434	383	166.2248	24%	39%	8%	16%	1%	1%	5%	30%	100%
2001	0.439	379	166.3934	25%	39%	8%	16%	1%	1%	5%	30%	100%
2002	0.444	380	168.8846	25%	39%	8%	16%	1%	1%	5%	30%	100%
2003	0.448	374	167.5418	26%	39%	8%	16%	1%	1%	5%	30%	100%
2004	0.455	376	170.9444	22%	22%	6%	18%	17%	3%	2%	32%	100%
2005	0.461	366	168.8481	27%	22%	5%	18%	16%	3%	2%	34%	100%
2006	0.469	363	170.1495	24%	28%	6%	19%	8%	2%	2%	35%	100%
2007	0.476	346	164.9551	20%	24%	6%	16%	9%	2%	2%	41%	100%
2008	0.484	345	166.9110	19%	27%	6%	14%	9%	2%	2%	39%	100%
2009	0.494	336	165.8160	18%	32%	7%	13%	9%	2%	2%	35%	100%
2010	0.502	336	168.7056	18%	32%	7%	13%	9%	2%	2%	35%	100%
2011	0.512	336	171.9648	18%	32%	7%	13%	9%	2%	2%	35%	100%
2012	0.525	336	176.3664	18%	32%	7%	13%	9%	2%	2%	35%	100%
2013	0.537	336	180.4198	18%	32%	7%	13%	9%	2%	2%	35%	100%
2014	0.550	336	184.6867	18%	32%	7%	13%	9%	2%	2%	35%	100%

Table 7-8 summarizes the quantities of waste that have been landfilled in Luxembourg. This data was prepared by the Environment Agency and is officially published by STATEC.

The relatively high figures for waste generation rate per capita is explained by the fact that, every working day, more than 150 000 commuters (*i.e.* around a quarter of the resident population) are crossing Luxembourg's borders to come to work (see Chapter 2). They, of course, generate important quantities of waste that are then divided by the resident population when estimating per capita figures.

Table 7-8 - Solid waste disposed on land (1990 - 2014)

Waste treated on SWDS sites							
Trend by landfill site							
Year	Total MSW tonnes	SIDEC tonnes	SIGRE tonnes	SIDA tonnes	Ronnebiertg tonnes	Population #	SWDL/capita kg/hab.
1990	87 634	58 234	18 400	11 000	NO	379 300	231.04
1991	74 540	39 340	24 600	10 600	NO	384 400	193.91
1992	53 672	38 111	5 461	10 100	NO	389 600	137.76
1993	66 029	39 259	13 712	13 058	NO	394 800	167.25
1994	64 074	45 526	18 548	NO	NO	400 200	160.10
1995	68 670	47 309	21 361	NO	NO	405 700	169.26
1996	94 064	51 021	43 043	NO	NO	411 600	228.53
1997	77 023	42 019	35 004	NO	NO	416 900	184.75
1998	75 737	41 898	33 839	NO	NO	422 100	179.43
1999	67 117	40 547	26 570	NO	NO	427 400	157.04
2000	61 728	41 600	20 128	NO	NO	433 600	142.36
2001	65 118	43 022	22 096	NO	NO	439 000	148.33
2002	65 952	41 780	24 172	NO	NO	444 000	148.54
2003	67 327	41 453	25 874	NO	NO	448 300	150.18
2004	59 459	35 535	23 924	NO	NO	455 000	130.68
2005	73 188	40 941	32 247	NO	NO	461 200	158.69
2006	64 528	34 362	30 166	NO	NO	469 100	137.56
2007	52 268	25 839	26 429	NO	NO	476 200	109.76
2008	51 819	25 095	26 724	NO	NO	483 800	107.11
2009	48 105	19 668	28 437	NO	NO	493 500	97.48
2010	55 654	20 890	34 764	NO	NO	502 100	110.84
2011	45 121	17 777	27 344	NO	NO	511 800	88.16
2012	46 535	18 439	28 096	NO	NO	524 900	88.65
2013	45 378	18 131	27 247	NO	NO	537 000	84.50
2014	44 980	17 734	27 245	NO	NO	549 700	81.83
<b>Trend 1990-2014</b>	-48.67%	-69.55%	48.07%	NA	NA	44.92%	-64.58%

Sources: STATEC, Statistical Yearbook, Table B.1100:

[http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=383&IF\\_Language=fra&MainTheme=2&FldrName=1](http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=383&IF_Language=fra&MainTheme=2&FldrName=1)

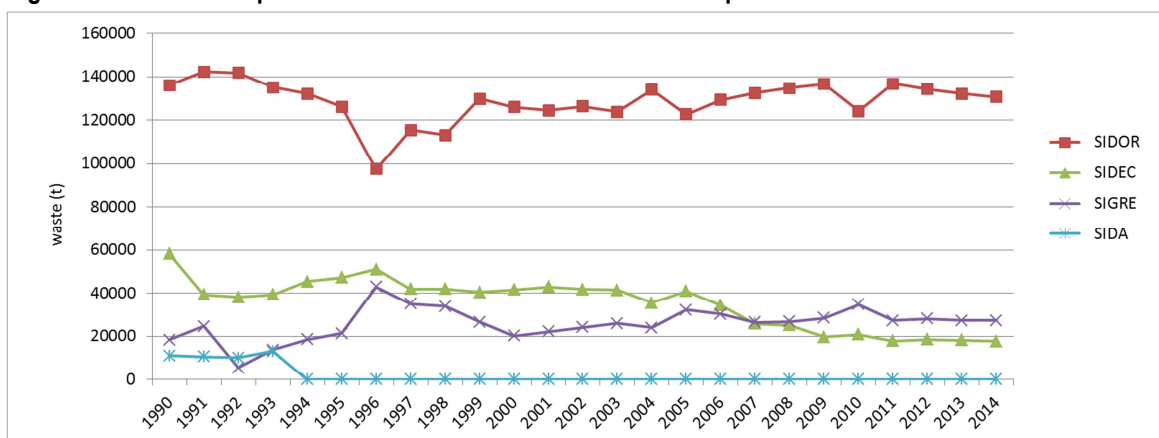
STATEC, Statistical Yearbook, Table A.3300:

[http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=365&IF\\_Language=fra&MainTheme=1&FldrName=3&RFPPath=65](http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=365&IF_Language=fra&MainTheme=1&FldrName=3&RFPPath=65)

The sharp increase of solid waste disposed at the SIGRE site and to a smaller extent at the SIDEC site in the year 1996 can be explained by a sharp decrease of waste incinerated at the SIDOR incineration site (shut-down for 3 months) due to a fire.<sup>151</sup> This strong relationship between waste incineration and SWDL is illustrated in Figure 7-3 below.

<sup>151</sup> De Journal, N.200, p.7, "SIDOR: Feiern in der Zeit des Umbruchs"

**Figure 7-3 - Relationship between waste incineration and waste disposal on land**



### 7.3.2.7 CH<sub>4</sub> Recovery

Recovery is only made since 2000. Data (from 2001 onwards) are from the annual reports from SIGRE and SIDER being sent to the Environment Agency in accordance to their permits. For the year 2000, no data is available, so that the IPCC default for non-monitored data was used.

### 7.3.3 Uncertainties and Time-Series Consistency

For uncertainties on activity data and emission factors, please refer to Section 1.7.

### 7.3.4 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 Eurostat Directive on reporting waste data. Indeed, the same aggregated data used for the inventory is also used for reporting to Eurostat.

### 7.3.5 Category-Specific Recalculations Including Changes Made in Response to the Review Process

Table 7-9 presents the main revisions and recalculations done relevant to CRF category 5A. For the quantitative aspect of these recalculations, please refer to Chapter 10.

**Table 7-9 - Changes in GHG inventory since submission 2014v1.4**

GHG source & sink category	Revisions 2014v1.4 → 2016 v1.2	Type of revision
5A - Recovery	2000: Methane recovery from solid waste disposal on land was set to zero ("NO") as no monitored data was available for that year, i.e. the IPCC default value was used.	Updated emissions. ARR 2013, §70
Transparency	Transparency was improved by changing some of the headings in Table 7-6	improved transparency

### 7.3.6 Category-Specific Planned Improvements

No planned improvements are foreseen in this sector.

## 7.4 Biological Treatment of Solid Waste (5B)

### 7.4.1 Source Category Description

Under IPCC Category 5B – *Biological Treatment of Solid Waste*, Luxembourg reports CH<sub>4</sub> and N<sub>2</sub>O emissions from compost production. This activity actually started up on a systematic “industrial scale” in the early 1990s: Emissions are reported from the year 1993 onwards.

In 2014, this source category was responsible for 19% of the total GHG emissions from the waste sector – excluding waste incineration – and it represented 0.09% of the total GHG emissions in CO<sub>2</sub>e (excluding LULUCF). For each of the two gases reported, in 2014:

- CH<sub>4</sub> represented 14.5% of waste treatment methane related emissions – excluding waste incineration – and 0.98% of the total methane emissions estimated for Luxembourg;
- N<sub>2</sub>O represented 34.45% of waste treatment nitrous oxide related emissions – excluding waste incineration – and 1.33% of the total nitrous oxide emissions estimated for Luxembourg.

Table 7-10 shows that CH<sub>4</sub> and N<sub>2</sub>O emissions, generated by compost production increased a lot over time as a result of the increasing amount of waste composted.

Table 7-10 – CH<sub>4</sub> & N<sub>2</sub>O emission trends for category 5B – *Biological Treatment of Solid Waste*: 1990-2014

5B - Biological Treatment of Solid Waste				
<i>Emissions (Gg)</i>				
Year	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Total in CO <sub>2</sub> e
1990	NO	NO	NO	NO
1991	NO	NO	NO	NO
1992	NO	NO	NO	NO
1993	NO	0.02	0.00	0.92
1994	NO	0.03	0.00	1.07
1995	NO	0.03	0.00	1.33
1996	NO	0.03	0.00	1.16
1997	NO	0.06	0.00	2.55
1998	NO	0.11	0.01	4.23
1999	NO	0.11	0.01	4.39
2000	NO	0.21	0.01	8.41
2001	NO	0.20	0.01	7.87
2002	NO	0.24	0.01	9.61
2003	NO	0.31	0.02	12.20
2004	NO	0.30	0.02	11.92
2005	NO	0.32	0.02	12.73
2006	NO	0.36	0.02	14.37
2007	NO	0.34	0.02	13.59
2008	NO	0.39	0.02	15.27
2009	NO	0.35	0.02	14.01
2010	NO	0.35	0.02	13.85
2011	NO	0.30	0.02	11.78
2012	NO	0.33	0.02	12.88
2013	NO	0.30	0.02	12.05
2014	NO	0.32	0.02	12.72
<i>Trend</i> 1993-2014	NA	1283.51%	1283.51%	1283.51%
<i>Trend</i> 2013-2014	NA	5.59%	5.59%	5.59%

Source: Environment Agency.

Note: The added emissions (*italic*) from 2000 onwards are those of the pilot project Soil-Concept.

Compost production is not a key category.

#### 7.4.2 Methodological Issues

The IPCC Tier 1 method has been applied to estimate both methane and nitrous oxide emissions from compost production. Default EFs have been used.

##### 7.4.2.1 Data Origin

Seven composting installations exist in LU, plus one that co-composts sewage sludge. The latter (“soil concepts” plant) uses active ventilation and operates fully aerobic – without methane formation. The other plants operate in part under anaerobic conditions, with a residence time in the composter of a few weeks. Emission calculation is performed using default factors from the IPCC guidelines, where also uncertainty estimates can be taken from.

### 7.4.2.2 Activity Data

Activity data are taken:

- from STATEC, *Statistical Yearbook*, Table A.3312 (these data are currently prepared by the Waste Division of the Environment Agency);
- from Soil-Concept annual reports transmitted to the Waste Division of the Environment Agency.

These activity data are presented in Table 7-11.

**Table 7-11 – Composting activities: 1995-2014**

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
<b>tonnes wet</b>																				
Total	8 398	7 354	16 083	26 685	27 729	37 169	34 088	38 424	53 310	51 692	54 817	57 242	58 196	59 628	63 866	62 202	47 798	54 109	52 106	56 678
kg/habitant	60.2	49.5	106.8	100.2	101.6	133.2	120.8	134.1	138.2	133.2	122.3	125	125.2	125.9	129.4	127.0	95.6	114.3	108.0	112.8
Minette-Kompost Mondercange (1)	4 534	3 767	11 773	17 345	20 520	24 146	23 234	25 421	24 462	27 514	28 746	28 743	30 173	30 614	32 237	30 868	29 977	32 411	31 774	34 329
kg/habitant	37.8	30.9	95.4	114.1	130.8	151.7	144.2	154.2	146.7	163.6	167.7	164	172.1	172.4	179.1	169.4	162.4	173.2	166.6	176.5
SICA Mamer	3 326	3 587	4 310	3 171	3 758	4 903	4 747	4 730	4 650	4 899	5 278	5 061	5 185	5 117	5 288	5 315	.	.	.	.
kg/habitant	170.1	133.5	158.7	115.6	135.2	176	170.1	167.5	164.5	172.2	181.8	170.4	174.6	164.9	168.7	166.7	.	.	.	.
SIDEC Fridhaff (3)	.	.	6 169	3 451	8 120	5 416	5 920	6 116	6 564	6 510	6 238	6 092	5 678	5 989	5 392	5 343	6 391	6 171	6 667	.
SIDEC Angelsberg (4)	.	.	.	.	.	691	2 353	2 174	2 534	2 651	2 670	2 702	1 917	2 219	1 784	1 815	2 491	2 343	2 549	.
kg/habitant	.	.	70.9	39.1	88.3	65.6	88.7	87.9	95.3	93.3	88.6	87.5	74.3	79	68.6	66.6	80.5	75.5	79.8	.
Commune de Hespérange	.	.	.	.	.	.	611.4	742	786	743	786	830	743	682	836	862	915	949	.	.
kg/habitant	.	.	.	.	.	.	50.4	59.2	59.9	54.9	58.1	59.3	51.1	45.4	54.6	55.3	65.2	66.9	.	.
Ville de Luxembourg/ Reckenthal	.	.	.	.	.	.	15 297	9 439	8 083	11 108	9 733	11 921	12 187	13 767	.	.	.	.	.	.
kg/habitant	.	.	.	.	.	.	181.5	113.2	97.5	122.8	107.6	128.4	125.1	140.4	.	.	.	.	.	.
SIGRE Muerlendall (5)	.	.	.	.	.	.	.	.	2 763	2 679	3 525	3 551	5 203	4 394	9 826	11 953	10 904	11 194	.	.
kg/habitant	.	.	.	.	.	.	.	.	51.4	48.5	63.8	63.3	91.1	67.5	61.2	74.5	66.1	65.9	.	.
Pélang (2)	538	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<b>tonnes dry</b>																				
Soil-Concept (6)	.	.	.	.	.	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

Source: Environment Agency.

- Notes:
- (1) New installation since May 1997
  - (2) Installation closed in 1996
  - (3) New installation running from 1998 onwards
  - (4) New installation running from 2001 onwards
  - (5) New installation running from 2005 onwards
  - (6) Soil-Concept pilot project started in 2000

### The Soil-Concept pilot project

This project aims at reducing direct spreading of sludge on agricultural lands thanks to the spreading of compost which is less harmful for the environment (see <http://www.soil-concept.lu>). Though most of the compost produced in the Soil-Concept installation is then used in agriculture, horticulture and viticulture, it seems logical to record associated emissions in IPCC Category 5B since these are "process" and not "spreading" emissions. Nevertheless, it is planned to further analyse the impact of sludge spreading and compost application on agriculture GHG emissions in order to refine these first estimates.

### 7.4.2.3 Emission Factors

EFs for compost production are actually default EFs for CH<sub>4</sub> and N<sub>2</sub>O emissions from biological treatment of waste taken from the 2006 IPCC Guidelines: see Table 7-12.

**Table 7-12 – Default EFs for CH<sub>4</sub> and N<sub>2</sub>O emissions from biological treatment of waste**

Type of biological treatment	CH <sub>4</sub> EF g CH <sub>4</sub> /kg waste treated	N <sub>2</sub> O EF g N <sub>2</sub> O/kg waste treated	Comment
------------------------------	---	--	---------

Composting excluding Soil-Concept project  Soil-Concept project	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.
	4	0.3	
	(0.03 - 8)	(0.06 - 0.6)	
	on a dry basis		
	10	0.6	
	(0.07-20)	(0.2-1.6)	

CH<sub>4</sub> and N<sub>2</sub>O emissions of biological treatment are estimated using the default method given in the following equations:

$$CH_4 \text{ emissions} = \sum_i (M_i \bullet EF_i) \bullet 10^{-3} - R$$

$$N_2O \text{ emissions} = \sum_i (M_i \bullet EF_i) \bullet 10^{-3}$$

Where:

CH<sub>4</sub> emissions = Total CH<sub>4</sub> emissions in inventory year [Gg CH<sub>4</sub>]

N<sub>2</sub>O emissions = Total N<sub>2</sub>O emissions in inventory year, [Gg N<sub>2</sub>O]

M<sub>i</sub> = Mass of organic waste treated by biological treatment type i [Gg]

EF<sub>i</sub> = Emission factor for biological treatment type i (see Table 7-23)

I = Composting or anaerobic digestion

R = Total amount of CH<sub>4</sub> recovered in inventory year [Gg CH<sub>4</sub>]<sup>152</sup>

#### 7.4.3 Uncertainties and Time-Series Consistency

For uncertainties on activity data and emission factors, please refer to Section 1.7.

#### 7.4.4 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.

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

No recalculations were done since submission 2014v1.4.

<sup>152</sup> So far, emission estimates for composting are not taking CH<sub>4</sub> recovery into account.

#### 7.4.6 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 7-13 will be explored.

**Table 7-13 – Planned improvements for IPCC Sub-category 5B – Biological Treatment of Solid Waste**

GHG source & sink category	Planned improvement
5B	No improvements are planned.

### 7.5 Incineration and Open Burning of Waste (5C)

This category is presented under IPCC Sub-category 1A1a – Fuel Combustion Activities – Energy Industries – Public Electricity and Heat Production (see Section 3.2.6 in Chapter 3) because in the sole incinerator of the country (SIDOR site), energy from waste burning is recovered and injected into the electric public network.

### 7.6 Waste Water Treatment and Discharge (5D)

#### 7.6.1 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 5D2) and industrial (Sub-category 5D1) 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<sub>2</sub> 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 5D1 covers nitrous oxide emissions from waste water treatment in industry, thus, emissions from IPCC Category 5D correspond to emissions deriving from IPCC Sub-category 5D1; emissions related to methane are not applicable ;
- IPCC Category 5D2 covers methane and nitrous oxide emissions from waste water treatment in residential and commercial sectors and septic tanks. No CO<sub>2</sub> 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 2014, this source category was responsible for 22.89% of the total GHG emissions from the waste sector – excluding waste incineration – and it represented 0.0014% of the total GHG emissions in CO<sub>2</sub>e (excluding LULUCF). For each of the two gases reported, in 2014:

- CH<sub>4</sub> from WWH represented 10.1% of waste treatment methane related emissions – excluding waste incineration – and 0.68% of the total methane emissions estimated for Luxembourg;
- N<sub>2</sub>O from WWH represented 65.5% of waste treatment nitrous oxide related emissions – excluding waste incineration – and almost 2.53% of the total nitrous oxide emissions estimated for Luxembourg.

None of the source categories under WWH is a key category.

### 7.6.2 Methodological Issues – Methane Emissions

Municipal waste water treatment in Luxembourg uses mainly aerobic processes (see Table 7-14) 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 7-14 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 7-14 – Municipal WWTP capacities and aerobic procedures: 1990-2014**

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%
1998	793.9	92%

Year	Load treated in municipal WWTP 1000 population-equivalents	Aerobic procedures %
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%
<b>Trend 1990-2014</b>	<b>80.24%</b>	<b>NA</b>

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<sub>4</sub>/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 (B<sub>0</sub>) 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:

$$MCF = 2/3 * 0.35 + 1/3 * 0.1 = 0.27$$

Calculation of the organic load:

$$BOD_{sep} [kg/year] = inhabitants\ connected\ to\ septic\ tanks * 60\ g\ BOD\ (person/day) * 365\ (days) / 1000$$

$$BOD_{mec} [kg/year] = inhab.\ connected\ to\ mechanical\ WWTP * 60\ g\ BOD\ (person/day) * 365\ (days) / 1000$$

Calculation of the methane emissions:

$$CH_4\ sep [t/year] = BOD_{sep} * B_0 * MCF / 1000 ;\ where : sep = septic\ tanks$$

$$CH_4\ mec [t/year] = BOD_{mec} * B_0 * MCF / 1000$$

Where:

mec = mechanical treatment plants

B<sub>0</sub> = 0.6 kg CH<sub>4</sub>/ 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 Interior and of the Greater Region - 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, and the last one in 2001, the evaluation is based on these population numbers for the years 2005-2009. The new census took place at the beginning of 2011, so that for submission 2015 a recalculation should be feasible for this period, depending on the publication date of the census.

Total methane emission from waste water handling:

$$CH_4\ tot = CH_4\ sep + CH_4\ mec [t/year]$$

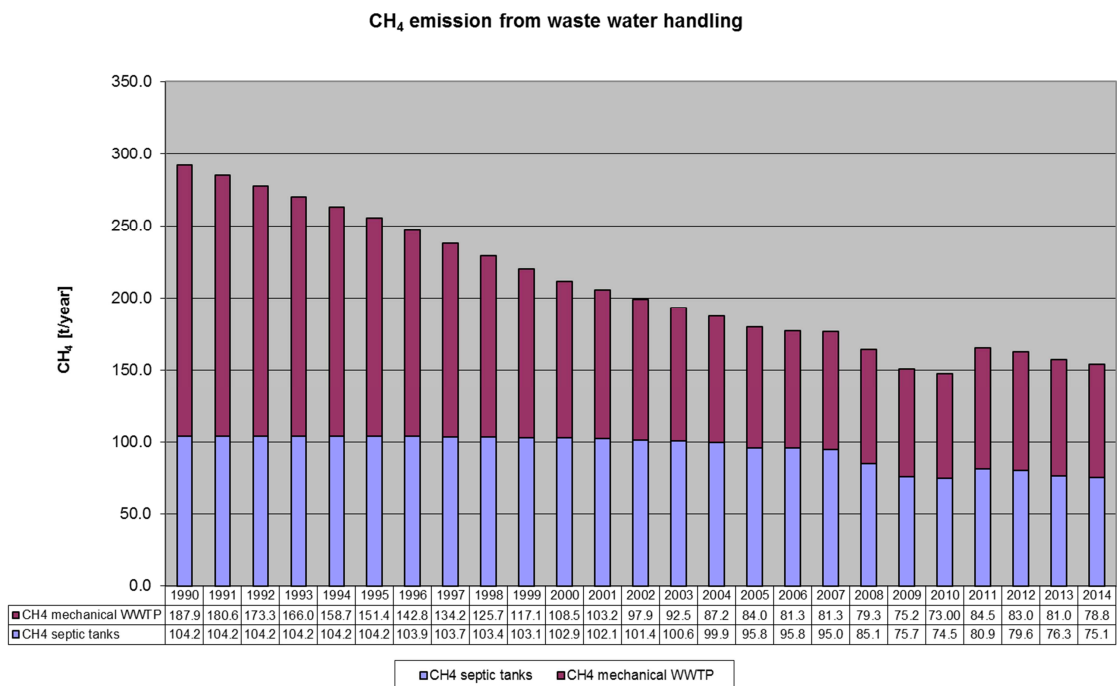
The estimated emissions, obtained following the method described above, are presented in Table 7-15 and Figure 7-4.

Table 7-15 – CH<sub>4</sub> emission trends for IPCC Sub-category 5B2 – Domestic & Commercial WWH: 1990-2014

CH <sub>4</sub> emissions (tonnes)			
5D1 - Domestic Waste Water			
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
Trend			
1990-2014	-58.06%	-27.90%	-47.31%

Source: Water Management Agency.

Figure 7-4 – CH<sub>4</sub> emission trends for category 5B2 – Domestic & Commercial WWH: 1990-2014



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.

### **7.6.3 Methodological Issues – Nitrous Oxide**

#### **7.6.3.1 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.

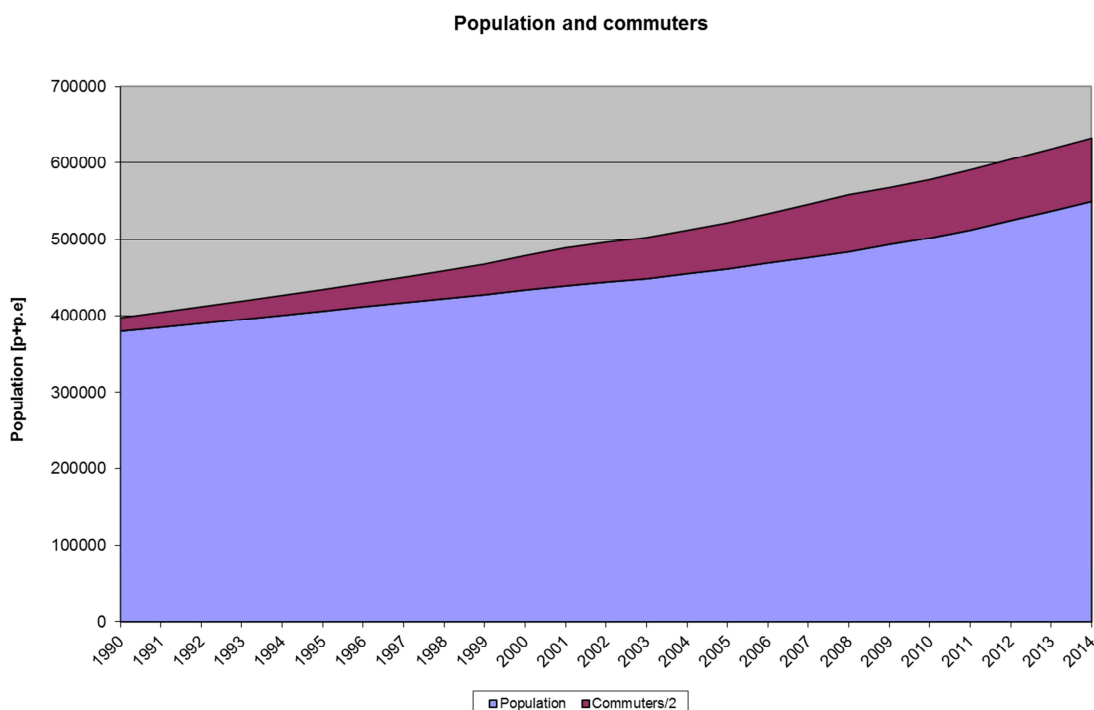
N<sub>2</sub>O emissions from urban waste water handling are calculated by distinguishing waste water arising from populations:

- a) not connected to a waste water treatment plant (WWTP)
- b) connected to a WWTP without denitrification
- c) connected to a WWTP with denitrification

The N<sub>2</sub>O emissions resulting from the population not connected to a WWTP were calculated according to 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 7-5 illustrates the population and cross-border commuters' growth between 1990 and 2014. 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 7-5 – Resident population and cross-border commuters: 1990-2014**



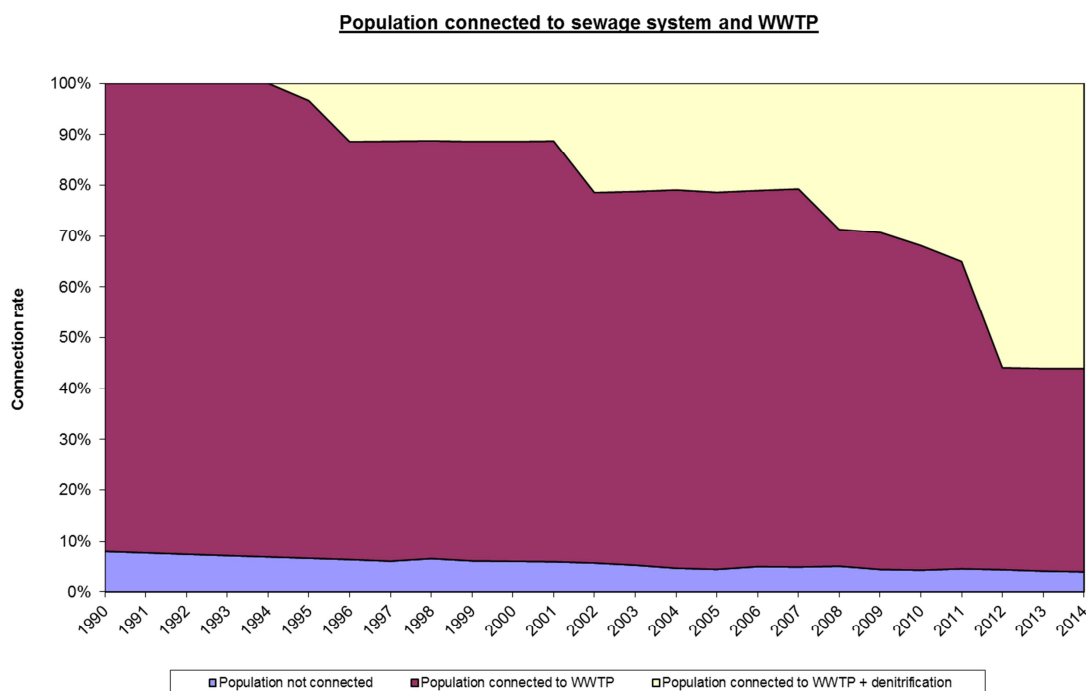
Sources: Le Portail des Statistiques au Luxembourg, *Statistical Yearbook*,  
[http://www.statistiques.public.lu/stat/TableView/tableView.aspx?ReportId=383&IF\\_Language=fra&MainTheme=2&FldrName=1&RFPPath=68](http://www.statistiques.public.lu/stat/TableView/tableView.aspx?ReportId=383&IF_Language=fra&MainTheme=2&FldrName=1&RFPPath=68)  
[http://www.statistiques.public.lu/stat/TableView/tableView.aspx?ReportId=494&IF\\_Language=fra&MainTheme=2&FldrName=3&RFPPath=92](http://www.statistiques.public.lu/stat/TableView/tableView.aspx?ReportId=494&IF_Language=fra&MainTheme=2&FldrName=3&RFPPath=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<sub>2</sub>O emissions the methodology of the 2006 IPCC Guidelines has been applied with a default value 3.2 g N<sub>2</sub>O 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 7-6 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 WWTPs with denitrification went online. Consequently, N<sub>2</sub>O emissions were reduced accordingly.

**Figure 7-6 – Population connected to sewage system and biological WWTP: 1990-2014**



Source: Water Management Agency.

Determination of  $N_2O$  from waste water not connected to a biological WWTP (2006 IPCC Guidelines):

$$N_2O_{nc} [t/year] = N_{effluent} * F_{ind-com} * EF_{effluent} / 1000 * 44/28$$

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:

$$N_2O_{wwtp} [t/year] = N_{effluent} / 1000 * \% FRAC_{denitri} * 0.01 * F_{ind-com} * 44/28$$

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 N<sub>2</sub>O (ORTHOFFER *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<sub>2</sub>O-N to N<sub>2</sub>O (44/28, N<sub>2</sub>O/N)

Determination of N<sub>2</sub>O from waste water connected to a biological WWTP with denitrification:

$$N_2O_{wwtp-de} = P * F_{ind-com} * EF_{plant} / 1.000.000 \quad [t/year]$$

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<sub>2</sub>O / person / year

Determination of N<sub>2</sub>O total emission from waste water handling:

$$N_2O_{mun\ tot} [t/year] = N_2O_{not\ connected} + N_2O_{connected\ to\ WWTP\ without\ denitrification} + N_2O_{connected\ to\ WWTP\ with\ denitrification}$$

Where:

mun = municipal waste water

The estimated emissions obtained following the method described above are presented in Table 7-16 and Figure 7-7.

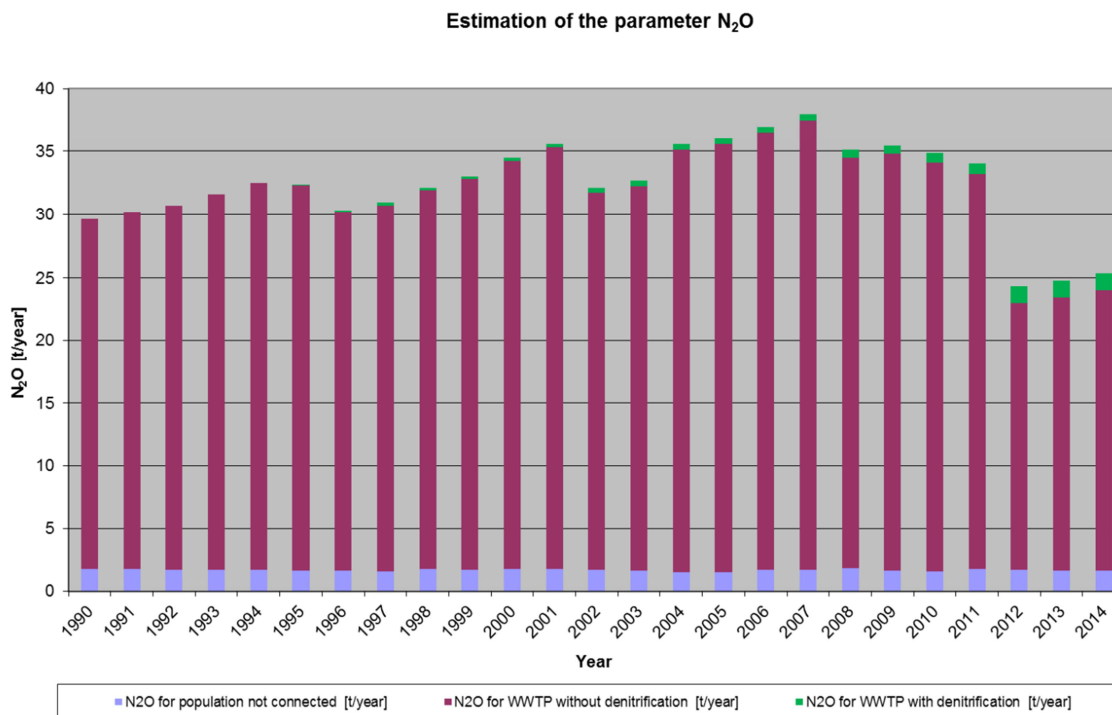
**Table 7-16 – N<sub>2</sub>O emission trends for category 5B2 – Domestic & Commercial WWH: 1990-2014**



N <sub>2</sub> O emissions (tonnes)				
5D1 - Domestic Waste Water				
Year	N <sub>2</sub> O nc	N <sub>2</sub> O wwtp	N <sub>2</sub> O 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
<b>Trend</b>				
<b>1990-2014</b>	-9.12%	-19.80%	596%	-14.35%

Source: Water Management Agency.

Figure 7-7 – N<sub>2</sub>O emission trends for category 5B2 – Domestic & Commercial WWH: 1990-2014



Source: Water Management Agency.

### 7.6.3.2 Nitrous Oxide Emissions from Industrial WWTP

N<sub>2</sub>O emissions from industrial waste water handling are issued from only one chemical plant that produces plastics and which releases N to aquatic environments. This industrial waste water treatment plant (WWTP) is equipped with a biological treatment with denitrification. N<sub>2</sub>O 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<sub>2</sub>O from waste water connected to an industrial waste water treatment plant with denitrification is calculated as follows:

$$N_2O_{ind} = N_{cc} [mg/l] * Inflow [m^3/a] / 1000 * \% FRAC_{denitri} * 0.01 * 44/28 \quad [t/year]$$

Where:

ind = industrial

N<sub>cc</sub> = N concentration in mg/l (measured data)

Inflow = flow in m<sup>3</sup>/year (measured data)

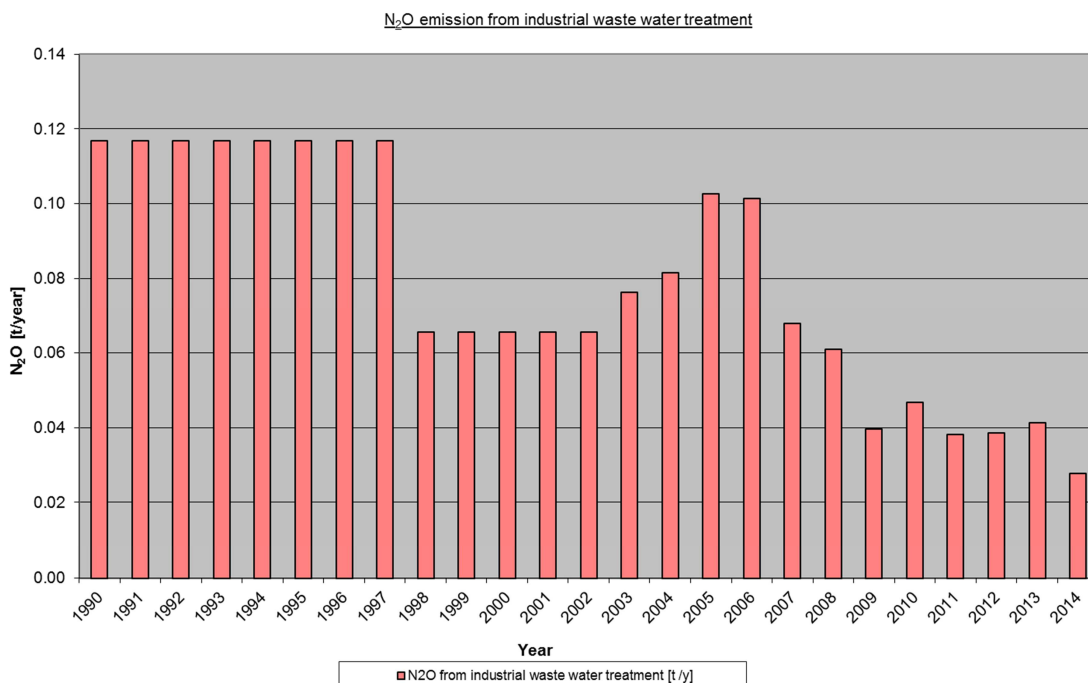
% FRAC<sub>denitri</sub> = 70% denitrification rate in % (% of waste water which is denitrified)

0.01 = 1% of the denitrified N is emitted as N<sub>2</sub>O (ORTHOFFER *et al.* 1995)

44/28 = 1.57, conversion of N<sub>2</sub>O-N to N<sub>2</sub>O (44/28, N<sub>2</sub>O/N)

The estimated emissions obtained following the method described above are presented in Figure 7-8.

**Figure 7-8 – N<sub>2</sub>O emission trends for category 5B1 – Industrial Waste Water WWH: 1990-2014**



Source: Water Management Agency.

### Determination of N concentration:

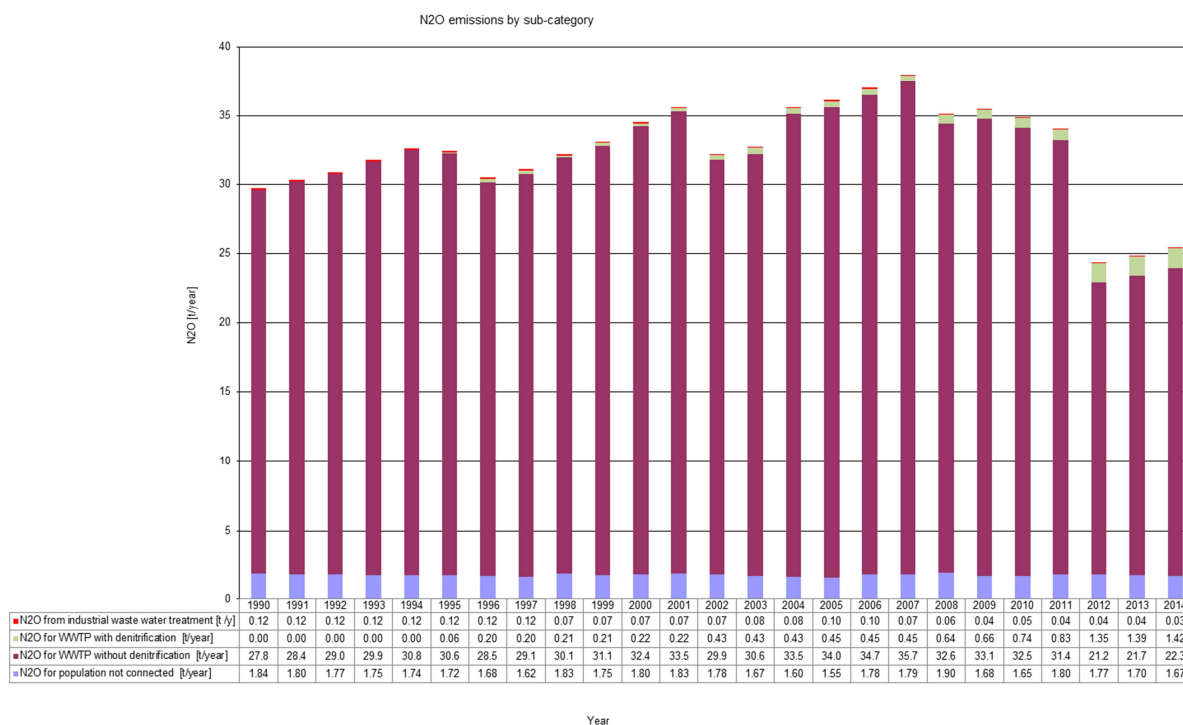
Year 1990 - 1997	Year 1998 - 2002	Year 2002 – 2014
N concentration extrapolated by expert judgment of the water management administration	N concentration extrapolated by expert judgment of the water management administration. In 1998 the WWTP has been upgraded allowing also denitrification	N concentration based on monitoring analyses

### 7.6.3.3 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 7-9 and Table 7-17.

**Figure 7-9 - N<sub>2</sub>O emission trends for category 5B1 and category 5B2 WWH: 1990-2014**



Source: Water Management Agency.

**Table 7-17 – N<sub>2</sub>O emission trends for category 5D1 and category 5D2 WWH: 1990-2014**

N <sub>2</sub> O emissions (tonnes)					
5D1 - Domestic & 5D2 - Industrial Waste Water					
Year	N <sub>2</sub> O nc	N <sub>2</sub> O wwtp	N <sub>2</sub> O wwtp-de	N <sub>2</sub> O 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
<b>Trend</b>					
<b>1990-2014</b>	-9.12%	-19.80%	2311%	-76%	-14.59%

Source: Water Management Agency.

#### 7.6.4 Uncertainties and Time-Series Consistency

- Waste water quantity: 10 % not connected to waste water treatment plants
- Emission factor for N<sub>2</sub>O: 50% (IPCC 2006 - Guidelines)
- Emission factor for CH<sub>4</sub>: 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.

#### 7.6.5 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 Luxembourg);
- 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).

#### **7.6.6 Category-specific recalculations including changes have been made in response to the review process**

Table 7-9 presents the main revisions and recalculations done relevant to CRF category 5D.

**Table 7-18 - Changes in GHG inventory since submission 2014v1.4**

GHG source & sink category	Revisions 2014v1.4 → 2016 v1.2	Type of revision
5D	No recalculations operated.	NA

#### **7.6.7 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 7-19 will be explored.

**Table 7-19 – Planned improvements for IPCC Category 5D – WWH**

GHG source & sink category	Planned improvement
5D2 – Domestic & Commercial WWH – CH <sub>4</sub>	List of WWTPs which produce methane gas for energy reuse in combined heat/power generating systems
5D2 – Domestic & Commercial WWH	The new census took place at the beginning of 2011, so that for the next submission a recalculation should be done for this period, depending on the publication date of the newest census

## **8 Other**

CRF Sector 6 is not applicable to Luxembourg's inventory.

## **9 Indirect CO<sub>2</sub> and nitrous oxide emissions<sup>153</sup>**

No indirect CO<sub>2</sub> and nitrous oxide emissions have been reported.

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<sup>153</sup> 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 CO<sub>2</sub> from the atmospheric oxidation of CH<sub>4</sub>, CO and NMVOCs. Annex I Parties may report as a memo item indirect N<sub>2</sub>O emissions from other than the agriculture and LULUCF sources. These estimates of indirect N<sub>2</sub>O should not be included in national totals. For Parties that decide to report indirect CO<sub>2</sub> the national totals shall be presented with and without indirect CO<sub>2</sub>.

## 10 Recalculations and Improvements

Table 10-1 summarises the main revisions and recalculations done since the last submission.

**Table 10-1 – Revisions and recalculations done since submission 2015v1**

GHG source & sink category	Revisions 2015v1 → 2016v1	Type of revision
Reference Approach - All fuels	AD was revised according to the revised energy balance and IEA Questionnaires as provided by STATEC	updated AD
Reference Approach - carbon contents / other parameters	All parameters and carbon contents were revised, if necessary, according to the 2006 IPCC Guidelines.	updated parameters
International Bunkers - Aviation	Activity data for Jet Kerosene for the years 2011 and 2013 was updated due to an update by the national statistics office to the energy balance. For 2011, the update resulted in a decrease of the consumption of 159 TJ and for 2013 in an increase of 7 TJ.	AD
1A1a	Fuel consumption data for natural gas were revised for the years 1995-1999 resulting in a decrease of emissions by 50 to 92 Gg CO <sub>2</sub> and for the years 2002 to 2010 resulting in a decrease of 0.7 to 2.4 Gg CO <sub>2</sub> due to an error correction in a formula.	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
1A2g.vii	Emission calculation for off-road vehicles and other machinery was changed to a T3 methodology using the GEORG model, leading to lower emissions than in previous submissions where T1 default EFs were used.	Updated methodology and EF
1A3a	Activity data were revised for 2011 and 2013 as provided by Statec.	updated AD
1A3b	Activity data were revised due to changes in the fuel consumption allocated to road transportation in the national energy balance provided by Statec. The resulting changes in total GHG emissions from 1A3b are in the range of 1-2%.	updated AD
1A3d	Updated gasoil AD for 2013 as provided by one of the two national operators. Updated diesel oil and gasoline AD for 2013 as provided by the operator of the marina in Schwabsange.	updated AD
1A4	AD for gasoil, natural gas and biomass was revised due to a revised energy balance by the national statistics institute.	updated AD
1A4b, 1A4c	Emission calculation for off-road vehicles and other machinery was changed to a T3 methodology using the GEORG model, leading to lower emissions than in previous submissions where T1 default EFs were used.	Updated methodology and EF
2D1	Relocation based on update reporting guidelines and CRF tables Methodology adapted to IPCC 2006 guidelines	Updated methodology
2D3.1	update of: <ul style="list-style-type: none"> <li>- data of the top-down approach: production statistics, import and export statistics</li> <li>- data of the bottom-up approach:</li> <li>- emission factors, type of waste gas treatment and solvent content by using information from solvents balances reported under the Solvent Ordinance.</li> <li>- plant specific, information from associations of industries and statistical data for "general aspects" and "specific aspects".</li> </ul>	updated 2D3.1
3A	Change to 2006 IPCC Methods, revision of activity data	Change of Methodology, updated AD
3B	Change to 2006 IPCC Methods, revision of activity data	Change of Methodology, updated AD
3D – N Input Manure to Soils	2005-2011 – revised fraction of livestock N excreted and deposited onto soil during grazing (Frac <sub>CRF</sub> ) following the revised AWMS shares for cattle (see 4B1).	a) revised activity data. b) revised parameter.
3D – PRP	1990-2013 – revised nitrogen excretion rate due to revised activity data	revised activity data.
3D – Atmospheric Deposition ...	2010 & 2011 –revised activity data for the horses sub-categories used for estimating the nitrogen excretion rate (see 4B6)	revised activity data.

GHG source & sink category	Revisions 2015v1 → 2016v1	Type of revision
4 - LULUCF areas	Reporting of land use changes (>269 ha) between grassland and cropland in the category cropland remaining cropland	revised AD ARR 2014, §67
4 – LULUCF	The results of the second NFI have been included in order to establish EF for forest growth, dead wood, harvest rate and biomass carbon stock	Revised EF ARR 2014, §61, §61, §63, §64
4 – LULUCF	Calculation of a country specific EF for carbon stock on cropland remaining cropland	Revised EF ARR 2014, §69
4 – LULUCF	Recalculation of uncertainties in line with the results from the second NFI	Revision of uncertainties ARR 2014, §60
4 – LULUCF Transparency	Transparency was improved by providing more detailed explanations on methodologies and assumptions made.	improved Transparency ARR 2014, §58, §59, §65, §68, §71
5A - Recovery	2000: Methane recovery from solid waste disposal on land was set to zero ("NO") as no monitored data was available for that year, i.e. the IPCC default value was used.	Updated emissions. ARR 2013, §70
5A - Transparency	Transparency was improved by changing some of the headings in Table 7-6	improved transparency ARR 2013, §69

Table 10-2, Table 10-3, Table 10-4 and Table 10-5 present the recalculations of CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O and total GHG emissions for the years 1990, 1995, 2000, 2005 and 2010-2013.



Table 10-2 – CO<sub>2</sub> emissions: recalculations done since submission 2015v1

CO <sub>2</sub>								
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Base year ( 1990 )	1995	2000	2005	2010	2011	2012	2013
	(Gg)	(Gg)	(Gg)	(Gg)	(Gg)	(Gg)	(Gg)	(Gg)
<b>1. Energy</b>	<b>0.66</b>	<b>-65.07</b>	<b>44.72</b>	<b>-110.81</b>	<b>-13.95</b>	<b>21.12</b>	<b>54.20</b>	<b>88.97</b>
A. Fuel Combustion (Sectoral Approach)	0.66	-65.07	44.72	-110.81	-13.95	21.12	54.20	88.97
1. Energy Industries	-	-60.43	-	-1.13	-1.20	0.00	0.00	-
2. Manufacturing Industries and Construction	0.58	5.01	-0.06	-0.08	18.16	68.87	71.30	110.13
3. Transport	-0.80	-15.43	44.79	-109.58	-29.25	5.31	39.96	61.61
4. Other Sectors	0.87	0.87	-	-0.02	-1.66	-53.06	-57.06	-82.77
5. Other	-	4.90	-	NO	NO	NO	NO	NO
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
<b>2. Industrial Processes</b>	<b>0.21</b>	<b>0.23</b>	<b>0.24</b>	<b>0.26</b>	<b>1.30</b>	<b>0.76</b>	<b>0.68</b>	<b>2.68</b>
A. Mineral industry	-	-	-	-	-	-	-	-
B. Chemical industry	NO	NO	NO	NO	NO	NO	NO	NO
C. Metal industry	-	-	-	-	-	-	-	-
D. Non-energy products from fuels and solvent use	0.21	0.23	0.24	0.26	1.30	0.76	0.68	2.68
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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G. Other product manufacture and use	NO	NO	NO	NO	NO	NO	NO	NO
H. Other	NO	NO	NO	NO	NO	NO	NO	NO
<b>3. Agriculture</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>
A. Enteric fermentation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B. Manure management	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C. Rice cultivation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D. Agricultural soils	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
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	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
<b>4. Land use, land-use change and forestry (2)</b>	<b>47.52</b>	<b>-567.86</b>	<b>-706.41</b>	<b>-642.97</b>	<b>-156.59</b>	<b>-278.40</b>	<b>-366.10</b>	<b>-541.65</b>
A. Forest land	-239.27	-854.65	-839.18	-775.54	-234.52	-355.02	-441.43	-615.66
B. Cropland	76.91	76.91	48.07	46.43	33.38	31.88	30.38	28.88
C. Grassland	49.10	49.10	-57.29	-49.10	-48.41	-44.37	-40.33	-36.30
D. Wetlands	13.97	13.97	12.29	11.67	7.60	7.12	6.64	6.16
E. Settlements	145.14	145.14	128.80	122.86	84.90	81.58	78.26	74.94
F. Other land	1.67	1.67	0.90	0.72	0.46	0.42	0.38	0.34
G. Harvested wood products	NO	NO	NO	NO	NO	NO	NO	NO
H. Other	NO	NO	NO	NO	NO	NO	NO	NO
<b>5. Waste</b>	<b>IE,NO</b>	<b>IE,NO</b>	<b>IE,NO</b>	<b>IE,NO</b>	<b>IE,NO</b>	<b>IE,NO</b>	<b>IE,NO</b>	<b>IE,NO</b>
A. Solid waste disposal	NO	NO	NO	NO	NO	NO	NO	NO
B. Biological treatment of solid waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C. Incineration and open burning of waste	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO
D. Waste water treatment and discharge	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E. Other	NO	NO	NO	NO	NO	NO	NO	NO
<b>6. Other (as specified in summary 1.A)</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>
<b>Memo items:</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>
<b>International bunkers</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-11.65</b>	<b>-</b>	<b>0.53</b>
Aviation	-	-	-	-	-	-11.65	-	0.54
Navigation	-	-	-	-	-	-	-	-0.02
<b>Multilateral operations</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>
<b>CO<sub>2</sub> emissions from biomass</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>0.00</b>	<b>-4.73</b>	<b>-3.72</b>	<b>-3.13</b>	<b>-3.49</b>
<b>CO<sub>2</sub> captured</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>
<b>Long-term storage of C in waste disposal sites</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>
<b>Indirect N<sub>2</sub>O</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>
<b>Total CO<sub>2</sub> excl. LULUCF</b>	<b>-1192.52</b>	<b>-1245.83</b>	<b>-1186.61</b>	<b>-1286.14</b>	<b>-1229.55</b>	<b>-1188.75</b>	<b>-1115.18</b>	<b>-1079.78</b>
<b>Total CO<sub>2</sub> incl. LULUCF</b>	<b>-1145.00</b>	<b>-1813.69</b>	<b>-1893.02</b>	<b>-1929.10</b>	<b>-1386.14</b>	<b>-1467.15</b>	<b>-1481.29</b>	<b>-1621.42</b>
<b>Total CO<sub>2</sub> incl. indirect CO<sub>2</sub> excl. LULUCF</b>	<b>0.87</b>	<b>-64.84</b>	<b>44.97</b>	<b>-110.55</b>	<b>-12.66</b>	<b>21.89</b>	<b>54.88</b>	<b>91.66</b>
<b>Total CO<sub>2</sub> incl. indirect CO<sub>2</sub> incl. LULUCF</b>	<b>48.38</b>	<b>-632.70</b>	<b>-661.45</b>	<b>-753.52</b>	<b>-169.25</b>	<b>-256.51</b>	<b>-311.22</b>	<b>-449.99</b>

Table 10-3 – CH<sub>4</sub> emissions: recalculations done since submission 2015v1

CH <sub>4</sub>								
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Base year ( 1990 )	1995	2000	2005	2010	2011	2012	2013
	(Gg)	(Gg)	(Gg)	(Gg)	(Gg)	(Gg)	(Gg)	(Gg)
<b>1. Energy</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>-0.01</b>	<b>-0.01</b>	<b>-0.01</b>	<b>-0.01</b>	<b>-0.01</b>
A. Fuel combustion (sectoral approach)	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01
1. Energy industries	-	0.00	-	0.00	0.00	-	-	-
2. Manufacturing industries and construction	0.00	0.00	0.00	-0.01	-0.01	0.00	0.00	0.00
3. Transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4. Other sectors	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01
5. Other	-	0.00	-	NO	NO	NO	NO	NO
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. CO <sub>2</sub> transport and storage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>2. Industrial processes</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>
A. Mineral industry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F. Product uses as ODS substitutes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G. Other product manufacture and use	NO	NO	NO	NO	NO	NO	NO	NO
H. Other	NO	NO	NO	NO	NO	NO	NO	NO
<b>3. Agriculture</b>	<b>0.04</b>	<b>0.04</b>	<b>0.04</b>	<b>0.05</b>	<b>0.05</b>	<b>0.05</b>	<b>0.04</b>	<b>0.04</b>
A. Enteric fermentation	0.04	0.04	0.04	0.05	0.05	0.05	0.04	0.04
B. Manure management	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
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	NO	NO	NO	NO	NO	NO	NO	NO
<b>4. Land use, land-use change and forestry (2)</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>
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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H. Other	NO	NO	NO	NO	NO	NO	NO	NO
<b>5. Waste</b>	<b>-</b>	<b>-0.03</b>	<b>-0.35</b>	<b>-0.45</b>	<b>-0.46</b>	<b>-0.41</b>	<b>-0.44</b>	<b>-0.10</b>
A. Solid waste disposal	-	-	-0.07	-0.03	-0.01	-0.01	-0.01	-
B. Biological treatment of solid waste	NE,NO	-	-0.06	-0.10	-0.10	-0.11	-0.11	-0.10
C. Incineration and open burning of waste	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO
D. Waste water treatment and discharge	-	-	-	-	-	-	-	-
E. Other	NO	-0.03	-0.21	-0.32	-0.35	-0.30	-0.33	NO
<b>6. Other (as specified in summary 1.A)</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>
<b>Total CH<sub>4</sub> emissions without CH<sub>4</sub> from LULUCF</b>	<b>0.04</b>	<b>0.00</b>	<b>-0.31</b>	<b>-0.41</b>	<b>-0.42</b>	<b>-0.38</b>	<b>-0.40</b>	<b>-0.06</b>
<b>Total CH<sub>4</sub> emissions with CH<sub>4</sub> from LULUCF</b>	<b>0.04</b>	<b>0.00</b>	<b>-0.31</b>	<b>-0.41</b>	<b>-0.42</b>	<b>-0.38</b>	<b>-0.40</b>	<b>-0.06</b>
<b>Memo items:</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>
<b>International bunkers</b>	-	-	-	-	-	-	-	0.00
Aviation	-	-	-	-	-	-	-	-
Navigation	-	-	-	-	-	-	-	0.00
<b>Multilateral operations</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>
<b>CO<sub>2</sub> emissions from biomass</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>
<b>CO<sub>2</sub> captured</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>
<b>Long-term storage of C in waste disposal sites</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>
<b>Indirect N<sub>2</sub>O</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>

Table 10-4 – N<sub>2</sub>O emissions: recalculations done since submission 2015v1

N <sub>2</sub> O								
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Base year ( 1990 )	1995	2000	2005	2010	2011	2012	2013
	(Gg)	(Gg)	(Gg)	(Gg)	(Gg)	(Gg)	(Gg)	(Gg)
<b>1. Energy</b>	0.00	0.00	0.00	-0.02	-0.04	-0.04	-0.02	-0.02
A. Fuel combustion (sectoral approach)	0.00	0.00	0.00	-0.02	-0.04	-0.04	-0.02	-0.02
1. Energy industries	-	0.00	-	0.00	0.00	-	-	-
2. Manufacturing industries and construction	0.00	0.00	0.00	-0.02	-0.03	-0.03	-0.01	-0.01
3. Transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4. Other sectors	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01
5. Other	-	0.00	-	NO	NO	NO	NO	NO
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. CO <sub>2</sub> transport and storage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>2. Industrial processes</b>	-	-	-	-	-	-	-	0.00
A. Mineral industry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F. Product uses as ODS substitutes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G. Other product manufacture and use	-	-	-	-	-	-	-	0.00
H. Other	NO	NO	NO	NO	NO	NO	NO	NO
<b>3. Agriculture</b>	-0.96	-0.89	-0.99	-0.85	-0.86	-0.90	-0.85	-0.87
A. Enteric fermentation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B. Manure management	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02
C. Rice cultivation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D. Agricultural soils	-0.93	-0.87	-0.97	-0.84	-0.85	-0.89	-0.84	-0.85
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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
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	NO	NO	NO	NO	NO	NO	NO	NO
<b>4. Land use, land-use change and forestry (2)</b>	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
A. Forest land	NO	NO	NO	NO	NO	NO	NO	NO
B. Cropland	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H. Other	NO	NO	NO	NO	NO	NO	NO	NO
<b>5. Waste</b>	-	0.00	-0.02	-0.03	-0.03	-0.03	-0.03	-0.01
A. Solid waste disposal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B. Biological treatment of solid waste	NE,NO	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
C. Incineration and open burning of waste	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO
D. Waste water treatment and discharge	-	-	-	-	-	-	-	-
E. Other	NO	0.00	-0.01	-0.02	-0.02	-0.02	-0.02	NO
<b>6. Other (as specified in summary 1.A)</b>	NO	NO	NO	NO	NO	NO	NO	NO
<b>Total direct N<sub>2</sub>O emissions without N<sub>2</sub>O from LULUCF</b>	-0.96	-0.89	-1.01	-0.91	-0.94	-0.97	-0.91	-0.90
<b>Total direct N<sub>2</sub>O emissions with N<sub>2</sub>O from LULUCF</b>	-0.94	-0.88	-0.99	-0.89	-0.93	-0.96	-0.90	-0.89
<b>Memo items:</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>International bunkers</b>	-	-	-	-	-	0.00	-	0.00
Aviation	-	-	-	-	-	0.00	-	0.00
Navigation	-	-	-	-	-	-	-	0.00
<b>Multilateral operations</b>	NO	NO	NO	NO	NO	NO	NO	NO
<b>CO<sub>2</sub> emissions from biomass</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>CO<sub>2</sub> captured</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Long-term storage of C in waste disposal sites</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Indirect N<sub>2</sub>O</b>	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO

Table 10-5 – Total GHG emissions: recalculations done since submission 2015v1

CO <sub>2</sub> equivalents								
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Base year ( 1990 )	1995	2000	2005	2010	2011	2012	2013
CO <sub>2</sub> equivalents	(Gg)	(Gg)	(Gg)	(Gg)	(Gg)	(Gg)	(Gg)	(Gg)
<b>1. Energy</b>	<b>0.49</b>	<b>-65.55</b>	<b>45.23</b>	<b>-116.98</b>	<b>-26.46</b>	<b>9.15</b>	<b>47.86</b>	<b>82.48</b>
A. Fuel combustion (sectoral approach)	0.49	-65.55	45.23	-116.98	-26.46	9.15	47.86	82.48
1. Energy industries	-	-60.48	-	-1.14	-1.20	0.00	0.00	-
2. Manufacturing industries and construction	0.44	4.93	0.21	-4.99	8.46	59.32	67.40	105.87
3. Transport	-0.72	-15.40	45.06	-109.95	-29.54	5.25	40.16	62.00
4. Other sectors	0.77	0.80	-0.03	-0.90	-4.19	-55.42	-59.70	-85.39
5. Other	-	4.60	-	-	-	-	-	-
B. Fugitive emissions from fuels	-	-	-	-	-	-	-	-
1. Solid fuels	-	-	-	-	-	-	-	-
2. Oil and natural gas and other emissions from ene	-	-	-	-	-	-	-	-
C. CO <sub>2</sub> transport and storage	NO	NO	NO	NO	NO	NO	NO	NO
<b>2. Industrial processes</b>	<b>0.21</b>	<b>0.23</b>	<b>0.24</b>	<b>0.26</b>	<b>1.30</b>	<b>0.76</b>	<b>0.68</b>	<b>2.54</b>
A. Mineral industry	-	-	-	-	-	-	-	-
B. Chemical industry	-	-	-	-	-	-	-	-
C. Metal industry	-	-	-	-	-	-	-	-
D. Non-energy products from fuels and solvent use	0.21	0.23	0.24	0.26	1.30	0.76	0.68	2.68
E. Electronic industry	-	-	-	-	-	-	-	-
F. Product uses as ODS substitutes	-0.88	-1.39	-1.93	-4.85	-6.87	-7.31	-7.68	-10.46
G. Other product manufacture and use	0.88	1.39	1.93	4.85	6.87	7.31	7.68	10.32
H. Other	-	-	-	-	-	-	-	-
<b>3. Agriculture</b>	<b>-283.78</b>	<b>-263.59</b>	<b>-293.54</b>	<b>-253.26</b>	<b>-255.74</b>	<b>-267.88</b>	<b>-253.51</b>	<b>-257.74</b>
A. Enteric fermentation	0.92	0.95	1.00	1.29	1.15	1.14	1.05	1.08
B. Manure management	-6.27	-4.84	-5.56	-4.81	-4.83	-5.01	-4.99	-4.68
C. Rice cultivation	-	-	-	-	-	-	-	-
D. Agricultural soils	-278.42	-259.70	-288.99	-249.75	-252.07	-264.00	-249.57	-254.13
E. Prescribed burning of savannas	-	-	-	-	-	-	-	-
F. Field burning of agricultural residues	-	-	-	-	-	-	-	-
G. Liming	-	-	-	-	-	-	-	-
H. Urea application	-	-	-	-	-	-	-	-
I. Other carbon-containing fertilizers	-	-	-	-	-	-	-	-
J. Other	-	-	-	-	-	-	-	-
<b>4. Land use, land-use change and forestry (2)</b>	<b>52.13</b>	<b>-563.24</b>	<b>-701.85</b>	<b>-638.66</b>	<b>-152.97</b>	<b>-274.98</b>	<b>-362.88</b>	<b>-538.62</b>
A. Forest land	-239.27	-854.65	-839.18	-775.54	-234.52	-355.02	-441.43	-615.66
B. Cropland	81.53	81.53	52.64	50.74	36.99	35.30	33.61	31.91
C. Grassland	49.10	49.10	-57.29	-49.10	-48.41	-44.37	-40.33	-36.30
D. Wetlands	13.97	13.97	12.29	11.67	7.60	7.12	6.64	6.16
E. Settlements	145.14	145.14	128.80	122.86	84.90	81.58	78.26	74.94
F. Other land	1.67	1.67	0.90	0.72	0.46	0.42	0.38	0.34
G. Harvested wood products	-	-	-	-	-	-	-	-
H. Other	-	-	-	-	-	-	-	-
<b>5. Waste</b>	<b>-</b>	<b>-1.74</b>	<b>-15.03</b>	<b>-20.91</b>	<b>-21.75</b>	<b>-19.22</b>	<b>-20.69</b>	<b>-5.04</b>
A. Solid waste disposal	-	-	-1.86	-0.77	-0.20	-0.21	-0.14	-
B. Biological treatment of solid waste	-	-0.15	-3.40	-5.37	-5.44	-5.41	-5.64	-5.04
C. Incineration and open burning of waste	-	-	-	-	-	-	-	-
D. Waste water treatment and discharge	-	-	-	-	-	-	-	-
E. Other	-	-1.59	-9.78	-14.77	-16.11	-13.61	-14.92	-
<b>6. Other (as specified in summary 1.A)</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>
<b>Memo items:</b>								
<b>International bunkers</b>	-	-	-	-	-	-11.76	-	0.53
Aviation	3.92	5.61	9.56	12.93	12.79	0.40	11.14	11.74
Navigation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
<b>Multilateral operations</b>	<b>-3.92</b>	<b>-5.61</b>	<b>-9.57</b>	<b>-12.93</b>	<b>-12.80</b>	<b>-12.16</b>	<b>-11.14</b>	<b>-11.20</b>
CO <sub>2</sub> emissions from biomass	-3.92	-5.61	-9.56	-12.93	-17.52	-15.88	-14.27	-14.69
CO <sub>2</sub> captured								
Long-term storage of C in waste disposal sites								
Indirect N <sub>2</sub> O								
<b>Total CO<sub>2</sub> excl. LULUCF</b>	<b>-283.07</b>	<b>-330.66</b>	<b>-263.10</b>	<b>-390.89</b>	<b>-302.67</b>	<b>-277.19</b>	<b>-225.66</b>	<b>-177.76</b>
<b>Total CO<sub>2</sub> incl. LULUCF</b>	<b>-230.94</b>	<b>-893.90</b>	<b>-964.94</b>	<b>-1029.55</b>	<b>-455.64</b>	<b>-552.17</b>	<b>-588.55</b>	<b>-716.38</b>
<b>Total CO<sub>2</sub> incl. indirect CO<sub>2</sub> excl. LULUCF</b>	<b>-283.07</b>	<b>-330.66</b>	<b>-263.10</b>	<b>-390.89</b>	<b>-302.67</b>	<b>-277.19</b>	<b>-225.66</b>	<b>-177.76</b>
<b>Total CO<sub>2</sub> incl. indirect CO<sub>2</sub> incl. LULUCF</b>	<b>-230.94</b>	<b>-893.90</b>	<b>-964.94</b>	<b>-1029.55</b>	<b>-455.64</b>	<b>-552.17</b>	<b>-588.55</b>	<b>-716.38</b>

Table 10-6 presents the recalculation differences of national total GHG emissions (excl. LULUCF) for 1990-2013 in Gg CO<sub>2</sub>eq and in %.

**Table 10-6 - Recalculation difference of national total GHG emissions (without LULUCF).**

year	total GHG emissions excl. LULUCF			
	submission	submission	recalculation	recalculation
	2016v1	2015v1.1	difference	difference
	Gg CO <sub>2</sub> eq	Gg CO <sub>2</sub> eq	Gg CO <sub>2</sub> eq	%
1990	12870.95	13154.02	-283.07	-2.15%
1991	13416.64	13717.61	-300.97	-2.19%
1992	13192.78	13482.32	-289.54	-2.15%
1993	13309.33	13583.04	-273.71	-2.02%
1994	12476.91	12742.16	-265.26	-2.08%
1995	10089.23	10419.89	-330.66	-3.17%
1996	10160.56	10489.19	-328.63	-3.13%
1997	9476.40	9843.97	-367.57	-3.73%
1998	8565.82	8962.99	-397.17	-4.43%
1999	8935.33	9317.14	-381.81	-4.10%
2000	9742.63	10005.72	-263.10	-2.63%
2001	10245.40	10499.19	-253.79	-2.42%
2002	11006.87	11309.54	-302.67	-2.68%
2003	11366.81	11746.26	-379.44	-3.23%
2004	12809.52	13241.42	-431.90	-3.26%
2005	13045.43	13436.32	-390.89	-2.91%
2006	12898.80	13268.44	-369.64	-2.79%
2007	12313.97	12676.55	-362.59	-2.86%
2008	12168.84	12475.71	-306.87	-2.46%
2009	11649.91	11939.81	-289.90	-2.43%
2010	12221.20	12523.87	-302.67	-2.42%
2011	12091.45	12368.64	-277.19	-2.24%
2012	11771.84	11997.50	-225.66	-1.88%
2013	11207.30	11385.06	-177.76	-1.56%

Table 10-7 summarises the planned improvements.

**Table 10-7– Planned improvements**

GHG source & sink category	Planned improvements
1A - Reference Approach	Provide a quantitative estimate of each separate discrepancy between RA and SA as outlined in Section 3.2.1.2.
1A - 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).
1A - Reference Approach	Other fossil fuels: add CO <sub>2</sub> 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.
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.
1A1a - Public Electricity and Heat Production	waste incineration with energy recovery: implement new waste composition analysis for the year 2015.
1A3b – Road Transportation	It is planned to reconduct a detailed study (such as the one carried out for the timeseries 1990- 2013) every few years in order to replace the projected data.
1A4a – Commercial/Institutional	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.
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.
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.
2D3.1	Investigate the possibility of acquiring more country-specific data in order to establish the emission levels from solvent and other product use. <sup>154</sup> Nevertheless, the IEF for CO <sub>2</sub> emission from Austria seemed to be more accurate and applicable than the default fossil carbon content fraction provided by the 2006 IPCC GL <sup>155</sup> because the IEF CO <sub>2</sub> is based on substance specific carbon dioxide factors for 15 substances. The amount of these substances used in Luxembourg (production/import/export) is taken into account in emission estimation.
2F2 – Foam blowing	continue the quest for country-specific data
2F4 – Aerosols	continue the quest for country-specific data
4A	Luxembourg plans to revise its OBS maps by 2018-2019
5D2 – Domestic & Commercial WWH – CH <sub>4</sub>	List of WWTPs which produce methane gas for energy reuse in combined heat/power generating systems

<sup>154</sup> ARR 2010, § 52 Solvent and other product use - CO<sub>2</sub>: Luxembourg bases its CO<sub>2</sub> emission estimates for this category on AD from Luxembourg using an implied CO<sub>2</sub> 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.

<sup>155</sup> “The default fossil carbon content fraction of NMVOC is 60 percent by mass, based on limited published national analyses of the speciation profile (U.S. EPA, 2002; Austria, 2004; Hungary, 2004; Klein Goldewijk et al., 2005). It may vary between 50 and 70 percent carbon by mass, so having an uncertainty of about  $\pm 10$  percent. Country-specific fractions should have a lower uncertainty, e.g.,  $\pm 5$  percent.” 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3, Chapter 5: Industrial Processes and Product Use, page 5.17, and 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 1, Chapter 7: Precursors and Indirect Emissions, page 7.6.

GHG source & sink category	Planned improvements
5D2 – Domestic & Commercial WWH	The new census took place at the beginning of 2011, so that for the next submission a recalculation should be done for this period, depending on the publication date of the newest census

## 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: <ul style="list-style-type: none"><li>• Minimum land area: 0.5 ha</li><li>• Minimum crown cover: 10 %</li><li>• Minimum height: 5 m.</li></ul> 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<sup>156</sup>, Luxembourg has decided, during the first commitment period, not to elect any of the activities under Article 3.4 of the Kyoto Protocol. In the second commitment period, Luxembourg has to carry out accounting for its forestry activities (forest management) according to Article 3 (4) of the Kyoto Protocol. 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 <sup>(1)</sup>							GREENHOUSE GAS SOURCES REPORTED <sup>(2)</sup>								
	Above-ground biomass	Below-ground biomass	Litter	Dead wood	Soil		HWP <sup>(4)</sup>	Fertilization <sup>(5)</sup>	Drained, rewetted and other soils <sup>(6)</sup>		Nitrogen mineralization in mineral soils <sup>(8)</sup>	Indirect N <sub>2</sub> O emissions from managed soil <sup>(5)</sup>	Biomass burning <sup>(9)</sup>			
					Mineral	Organic <sup>(3)</sup>			N <sub>2</sub> O	CH <sub>4</sub> <sup>(7)</sup>	N <sub>2</sub> O	N <sub>2</sub> O	N <sub>2</sub> O	CO <sub>2</sub> <sup>(10)</sup>	CH <sub>4</sub>	N <sub>2</sub> O
Article 3.3 activities																
Afforestation and reforestation	R	R	R	R	R	NO	IO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Deforestation	R	R	R	R	R	NO	IO	NO	NO	NO	NO	NO	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	NO
Cropland management	NR	NR	NR	NR	NR	NA			NA		NA		NA	NA	NA	NA
Grazing land management	NR	NR	NR	NR	NR	NA			NA		NA		NA	NA	NA	NA
Revegetation	NR	NR	NR	NR	NR	NA		NA	NA	NA	NA	NA	NA	NA	NA	NA
Wetland drainage and rewetting	NR	NR	NR	NR		NA		NA	NA	NA		NA	NA	NA	NA	NA

### 11.1.3 Provision for carbon equivalent forests

Luxembourg has not elected the provision for carbon equivalent forests.

### 11.1.4 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.)

<sup>156</sup> [http://unfccc.int/files/national\\_reports/initial\\_reports\\_under\\_the\\_kyoto\\_protocol/application/pdf/mev\\_initial\\_report\\_0612.pdf](http://unfccc.int/files/national_reports/initial_reports_under_the_kyoto_protocol/application/pdf/mev_initial_report_0612.pdf)

Luxembourg has developed a background level and a margin for natural disturbances according to the methodology described in IPCC KP Supplements (2014):

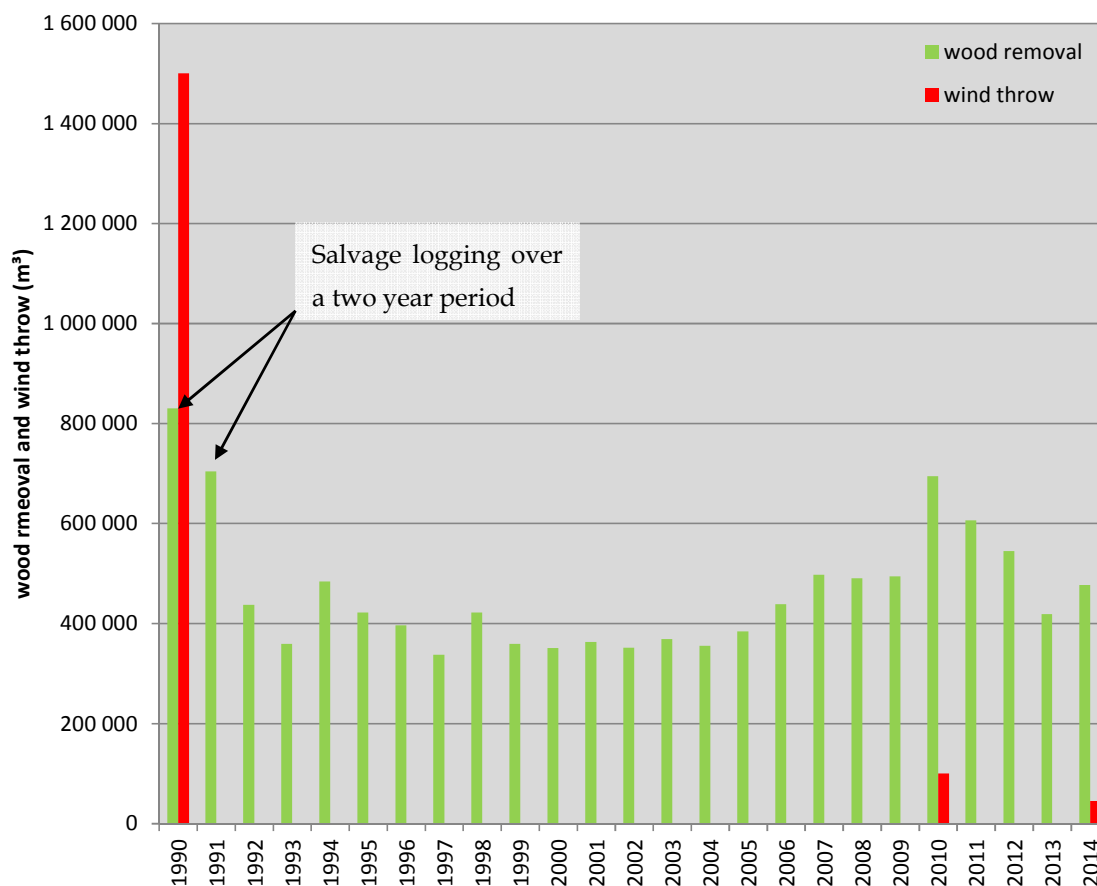
Step 1: Define the type of natural disturbances that the Party wishes to exclude from accounting:

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 11-2 – 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 11-2 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. The comparison of the data as well as expert opinion confirm that most of the wood lost through the wind storms has been 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 outliers. 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.

### **11.1.5 Description of how the definitions of each activity under Article 3.3 have been implemented and applied consistently over time**

#### **11.1.5.1 Afforestation, reforestation and deforestation (ARD)**

The area of forest land reported for Afforestation/Reforestation (AR) and Deforestation (D) under the Kyoto Protocol has the same basis as the area reported for Land use changes from and to forests in the UNFCCC greenhouse gas inventory 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	-0.44	0.70	79.31	14.00
1991	92.18	-0.88	1.40	79.57	14.00
1992	91.73	-1.32	2.10	79.83	14.00
1993	91.29	-1.76	2.80	80.09	14.00
1994	90.85	-2.20	3.50	80.35	14.00
1995	90.41	-2.64	4.20	80.61	14.00
1996	89.97	-3.08	4.90	80.87	14.00
1997	89.53	-3.52	5.60	81.12	14.00
1998	89.08	-3.96	6.30	81.38	14.00
1999	88.64	-4.40	7.00	81.64	14.00
2000	88.52	-4.54	7.18	82.21	13.48
2001	88.39	-4.68	7.36	82.79	12.96
2002	88.26	-4.81	7.53	83.36	12.43
2003	88.13	-4.95	7.71	83.93	11.91
2004	88.01	-5.09	7.89	84.50	11.39
2005	87.88	-5.22	8.06	85.08	10.86
2006	87.75	-5.36	8.24	85.65	10.34
2007	87.62	-5.49	8.42	86.22	9.82
2008	87.58	-5.53	8.47	86.88	9.17
2009	87.54	-5.57	8.52	87.54	8.52
2010	87.50	-5.61	8.58	88.20	7.88
2011	87.47	-5.65	8.63	88.87	7.23
2012	87.43	-5.69	8.68	89.53	6.58
2013	87.39	-5.73	8.73	90.19	5.93
2014	87.35	-5.77	8.79	90.85	5.29

#### 11.1.5.2 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 UNFCCC 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 UNFCCC 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.

#### **11.1.5.3 Cropland management (CM)**

Luxembourg has not elected CM.

#### **11.1.5.4 Grazing land management (GM)**

Luxembourg has not elected GM.

#### **11.1.5.5 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 has not selected 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.

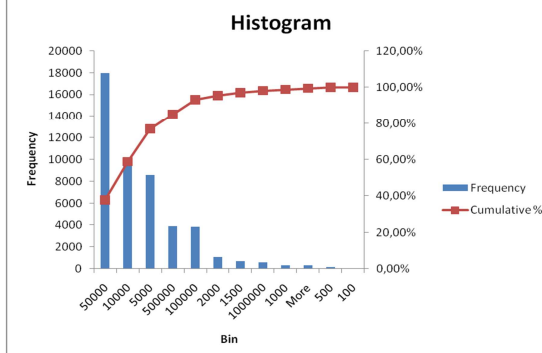
### 11.2.1 Spatial assessment unit used for determining the area of the units of land under Article 3.3

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 <sup>2</sup> ) 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%

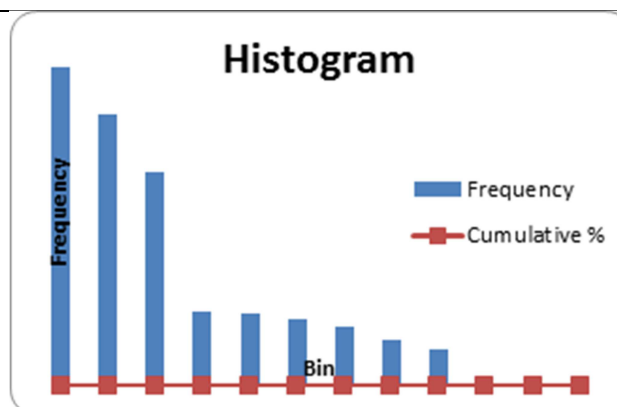


**Figure 11-3 - Histogram of OBS89 data: Frequency of Polygons in size classes**

The OBS99 MMU is in principle 2500 m<sup>2</sup> (0.25 ha) but adapted for important but small areas, i.e. wetlands and little lakes/ponds to 1500 m<sup>2</sup> (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 <sup>2</sup> ) 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%

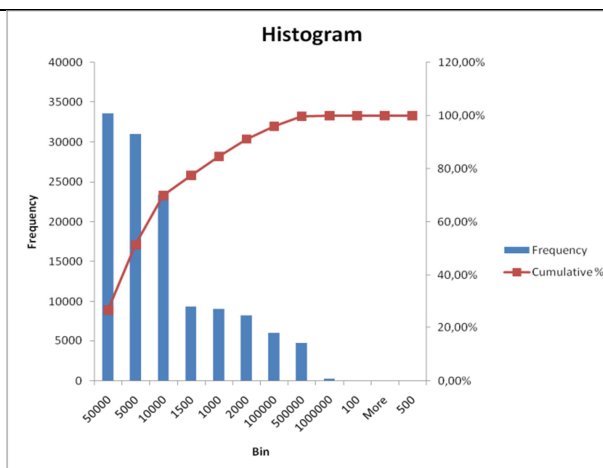


**Figure 11-4 - Histogram of OBS99 data: Frequency of Polygons in size classes**

The OBS07 MMUs correspond to those of the OBS99 with changes from OBS99 to OBS07 mapped with a MMU of 500 m<sup>2</sup>. 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 <sup>2</sup> ) 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 11-5 - Histogram of OBS07 data: Frequency of Polygons in size classes**

### 11.2.2 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.

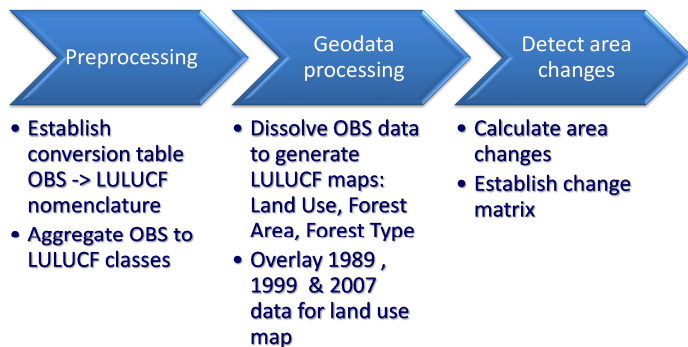


The original OBS categories for the years 1989, 1999 and 2007 were assigned to the relevant classes of the LULUCF nomenclatures. The correspondence of OBS89 respectively OBS99/07 classification to the LULUCF nomenclature has been established in close collaboration with the relevant administrations and 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.

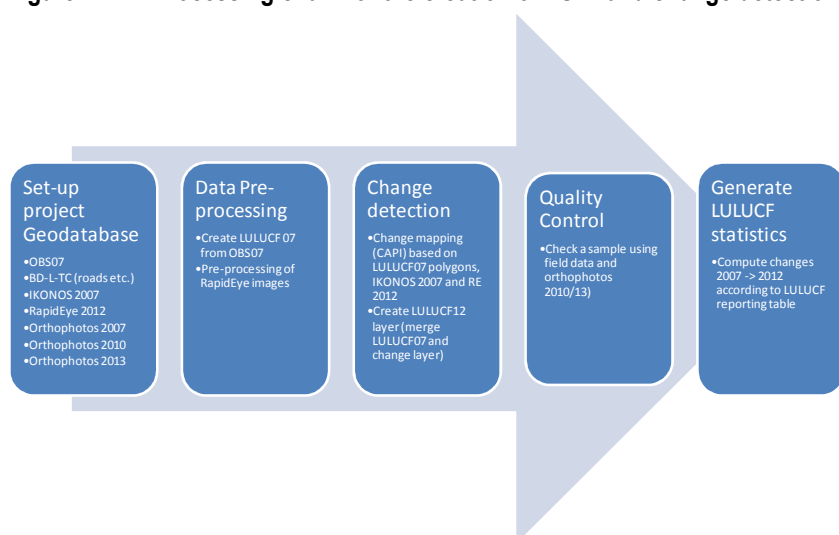
In order to preserve the detail in the data for the generation of the area statistics, no generalisation was performed before the change detection. Change detection of Land Use / Forest types between the selected reference years 1989, 1999 and 2007 has been carried out by overlay (intersect) of the Land Use maps LU89, LU99 and the LU07 data sets. Figure 11-5 shows the processing steps.

**Figure 11-6 – 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 11-7 – 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<sup>2</sup>. 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 Luxembourg, and especially in the northern part of Luxembourg (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”.

### 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 and 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<sup>157</sup>:

**Table 11-5 – OBS89 Nomenclature at level1 and number of classes in levels 2-6**

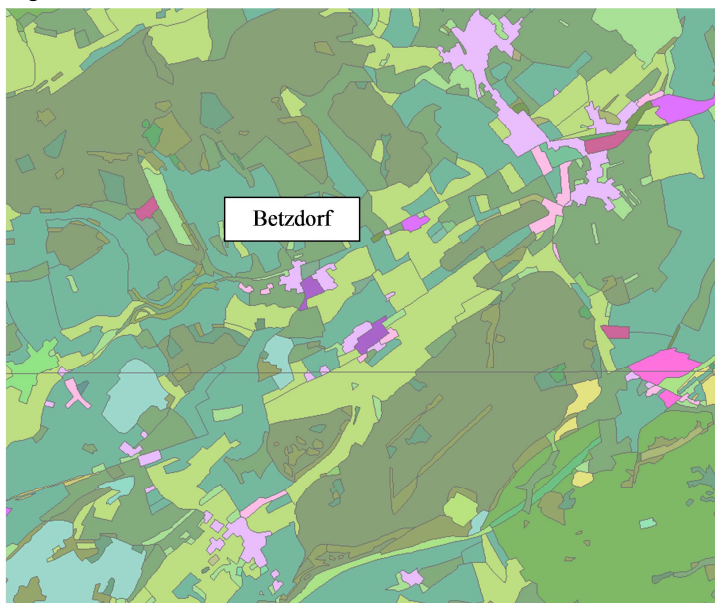
Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
Artificial areas	4	11	22	27	
Agricultural areas	3	4	9	10	3

<sup>157</sup> Source: Ministère de l’environnement (1994): Cartographie de l’occupation biophysique du sol 1988 – Légende – Luxembourg

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<sup>2</sup>, 580 polygons smaller than 1000 m<sup>2</sup> 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 11-8 – 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<sup>2</sup> (0.25 ha) but adapted for important but small areas, i.e. wetlands and little lakes/ponds to 1500 m<sup>2</sup> (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.

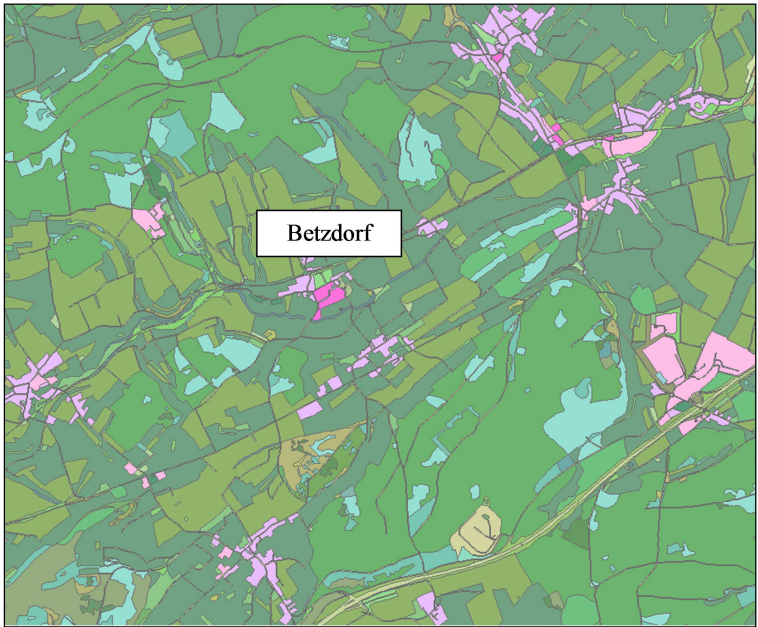
The map includes 4 landscape element categories (isolated tree, group of isolated trees, tree rows, hedges) and in total 77 land use/cover classes, divided in 5 broad categories:

**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 11-9 – Subset of the OBS99 with its 76 classes**



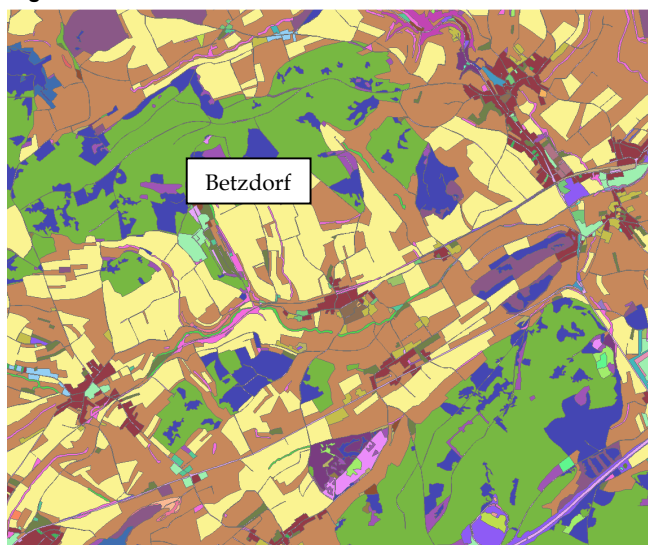
The data has been used for LULUCF mapping for the year 1999.

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, who is responsible for the quality of this data product. 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 500m<sup>2</sup>. 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 11-10 – Subset of OBS07 with its 76 classes**



#### RapidEye Satellite land use map LU12

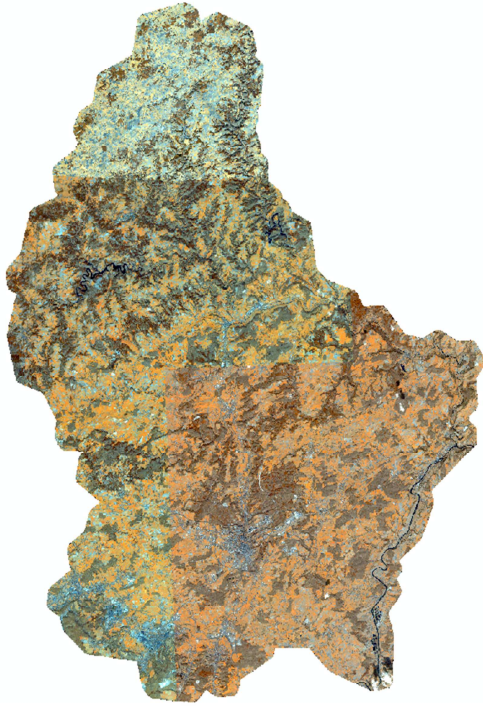
The RapidEye (RE) space segment is composed of five sun-synchronous Earth observation satellites providing large area, multi-spectral images with frequent revisits in high resolution (5m).

RapidEye characteristics	
<b>Launch date</b>	28/08/2008, constellation of 5 satellites
<b>Orbit</b>	Sun synchronous, 11:00h desc. Node, 96,7 minutes period, 630 km altitude
<b>Sensor bands</b>	Multispectral 5 bands, 6.5*6.5m <sup>2</sup> native sensor resolution, or resampled to <b>5m</b> pixelsize 1: Blue 440-510nm 2: Green 520-590nm 3: Red 630-690nm 4: Red Edge 690-730nm 5: Near IR 760-880nm
<b>Swath-width</b>	77km
<b>Revisit Frequency</b>	Daily

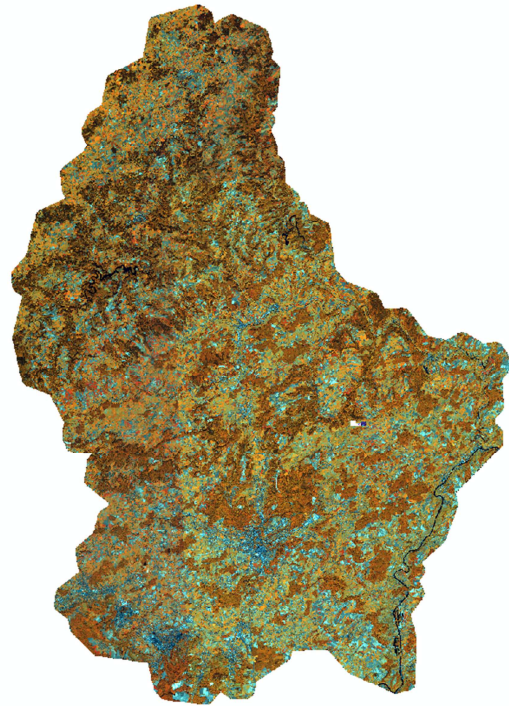
In preparation for this project, multi-temporal RapidEye images have been acquired in March, April and in August 2012 covering the entire Luxembourg territory. Multi-temporal imagery analysis means that the interpretation is based on at least 2 images over the Area of Interest (AOI) at different points 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 km<sup>2</sup>. 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	C before LUC (tC/ha*y)	Biomass Growth		Soil	
		Age class: 0-20 years (tC/ha*y)	Age class: 20-40 years (tC/ha*y)	C stock change after 20 years of LUC (tC/ha)	annual C stock change (tC/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

#### 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		Dead wood & litter	Soil	
	C before LUC (tC/ha*yr)	Growth (tC/ha*yr)	C before LUC (tC/ha*yr)	C stock change after 20 years of LUC (tC/ha)	annual C stock change (tC/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 <sub>2</sub> O (Gg N <sub>2</sub> O)
	above	below	litter	dead wood	Bio- mass	Soil	Bio- mass	Soil	Bio- mass	Soil	Bio- mass	Soil	Bio- mass	Soil	
	<b>OTHER under KP</b>														
1990	-40.1	-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	-0.000
2013	-4.2	-0.9	-0.8	-0.2	0.06	-1.04	0.12	-1.02	0.00	-0.42	0.24	-3.77	0.00	-0.06	-0.001
2014	-4.2	-0.9	-0.8	-0.2	0.06	-0.92	0.12	-0.90	0.00	-0.38	0.24	-3.52	0.00	-0.05	-0.001

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. From 2009 onwards all forests that are less than 20 years old are included within the AR category and have not to be accounted for under FM.

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) <sup>158</sup>				
	Biomass gains (GgC)		Biomass loss (GgC)		DOM (GgC)		Biomass gains (GgC)		soil	litter	dead wood
	above	below	above	below	litter	dead wood	above	below			
1990	205.02	43.88	-219.81	-47.22	0.00	0.00	34.58	6.97	25.09	12.77	3.13
2013	222.24	-124.55	47.73	-26.43	0.00	0.00					
2014	221.22	-140.90	47.56	-29.78	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 UNFCCC (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 forest code, that will be published this year, will 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 all chapters have been revised mainly by including the data from the second forest inventory.

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<sup>158</sup> Carbon gain due to Land converted to forestland before 1990 and not reported under afforestation.

#### **11.3.1.5 Uncertainty estimates**

An uncertainty assessment of emissions/removals of the ARD and FM units is foreseen in 2016, depending on the availability of financial resources.

#### **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 to determine the differences in land use since the 1<sup>st</sup> 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 <sup>a</sup> at the end of this section)."*<sup>159</sup>.

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<sup>159</sup> 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)

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.

A further possibility for deriving such data would be the use of Luxembourg's second national forest inventory (NFI). The first forest inventory results are from 1999. The results for the second forest inventory were only recently published (March 2014<sup>160</sup>). But the use of the second NFI would allow estimating the changes in land use, as well from forestland to non-forestland as from non-forestland to forestland. That particular statistic is currently being analysed and will be published with the 2017 submission.

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, 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 nationwide 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.

#### Maintenance of agricultural land in good agricultural and environmental conditions

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:

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<sup>160</sup> La forêt luxembourgeoise en chiffres - Résultats de l'Inventaire Forestier National au Grand-Duché de Luxembourg 2009 - 2011: [http://www.environnement.public.lu/forets/publications/IFL2\\_fr/IFL2\\_-PDF\\_interactif\\_LR.pdf](http://www.environnement.public.lu/forets/publications/IFL2_fr/IFL2_-PDF_interactif_LR.pdf)

### *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 the 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<sup>161</sup>, cf. article 9 paragraph 2 and Annex II of this regulation (in French).

#### **Chapitre VII: Conditionnalité**

**Art. 9. (1)** Aux fins de l'application des exigences réglementaires visées à l'article 4 du règlement (CE) n° 1782/2003, en ce qui concerne la mise en oeuvre des directives 79/409/CEE du Conseil du 2 avril 1979 concernant la conservation des oiseaux sauvages et 92/43/CEE du Conseil du 21 mai 1992 concernant la conservation des habitats naturels ainsi que de la faune et de la flore sauvages visées à l'annexe III du règlement (CE) n° 1782/2003, 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 du 19 janvier 2004 concernant la protection de la nature et des ressources naturelles sont fixées à l'annexe I du présent règlement.

(2) En application de l'article 5 du règlement (CE) n° 1782/2003, les exigences minimales pour les bonnes conditions agricoles et environnementales sont fixées à l'annexe II du présent règlement.

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.

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<sup>161</sup> Règlement Grand-Ducal du 8 avril 2005 portant certaines mesures d'application, au Grand-Duché de Luxembourg, du régime de paiement unique et de la conditionnalité dans le cadre de la politique agricole commune.

#### **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 reconstruct the forestland.*<sup>162</sup> 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

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<sup>162</sup> See section 1.4.4. for the original French text of article 13.

- « 32415 recrues 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 Recrues 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**

**Forest management**

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" 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 1645 ha (2014) which represents 1,7 % 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)

In order to encourage a sustainable exploitation in public forests a range of legislation is available:

- 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 forest 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 this year.

#### 11.5.4 Forest Management Reference Levels (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, an FMRL of -0.418 MtCO<sub>2</sub>-eq per year has been 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>. For that reason 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. It is not clear how the FMRL for Luxembourg has been calculated by the EU and thus a review and eventually a technical correction might have to be provided in subsequent submissions.

#### 11.6 Other information

##### 11.6.1 Key category analysis for Article 3.3 activities and any elected activities under Article 3.4

Land use changes to forestland and FM are considered key categories.

Table 11-13 – Overview of key categories for LULUCF activities under the Kyoto Protocol (CRF – NIR 3 table)

KEY CATEGORIES OF EMISSIONS AND REMOVALS		CRITERIA USED FOR KEY CATEGORY IDENTIFICATION			Comments <sup>(4)</sup>
		Associated category in UNFCCC inventory <sup>(1)</sup> is key (indicate which category)	Category contribution is greater than the smallest category considered key in the UNFCCC inventory <sup>(2)</sup> (including LULUCF)	Other <sup>(3)</sup>	
	Gas				
Specify key categories according to the national level of disaggregation used <sup>(1)</sup>					
Afforestation and Reforestation					
CO <sub>2</sub>	CO <sub>2</sub>	Land converted to forest land	Yes	none	no comments
Forest Management					
CO <sub>2</sub>	CO <sub>2</sub>	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. 2015, 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, ICERs, AAUs and RMUs for the year 2015 was submitted to the UNFCCC on April 15<sup>th</sup>, 2016 (RREG1\_LU\_2015.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 2015.
- Paragraph 13: No CDM notification occurred in 2015.
- Paragraph 14: No CDM notification occurred in 2015.
- Paragraph 15: No non-replacements occurred in 2015.
- Paragraph 16: No invalid units exist as of 31 December 2015.
- 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)**

The CPR will be calculated once Luxembourg has submitted its Initial Report for CP2.

## **12.6 KP-LULUCF accounting**

Luxembourg selected accounting of the KP-LULUCF activities at the end of the commitment period.

### ***13 Information on changes in national system***

The national system is unchanged compared to the description given in the previous National Inventory Report. However, human resources have been increased since the last submission.

### ***14 Information on changes in national registry***

Directive 2009/29/EC adopted in 2009, provides for the centralization of the EU ETS operations into a single European Union registry operated by the European Commission as well as for the inclusion of the aviation sector. At the same time, and with a view to increasing efficiency in the operations of their respective national registries, the EU Member States who are also Parties to the Kyoto Protocol (25) plus Iceland, Liechtenstein and Norway decided to operate their registries in a consolidated manner in accordance with all relevant decisions applicable to the establishment of Party registries - in particular Decision 13/CMP.1 and decision 24/CP.8.

With a view to complying with the new requirements of Commission Regulation 920/2010 and Commission Regulation 1193/2011, in addition to implementing the platform shared by the consolidating Parties, the registry of EU has undergone a major re-development. The consolidated platform which implements the national registries in a consolidated manner (including the registry of EU) is called Consolidated System of EU registries (CSEUR) and was developed together with the new EU registry on the basis of the following modalities:

- Each Party retains its organization designated as its registry administrator to maintain the national registry of that Party and remains responsible for all the obligations of Parties that are to be fulfilled through registries;
- Each Kyoto unit issued by the Parties in such a consolidated system is issued by one of the constituent Parties and continues to carry the Party of origin identifier in its unique serial number;
- Each Party retains its own set of national accounts as required by paragraph 21 of the Annex to Decision 15/CMP.1. Each account within a national registry keeps a unique account number comprising the identifier of the Party and a unique number within the Party where the account is maintained;
- Kyoto transactions continue to be forwarded to and checked by the UNFCCC Independent Transaction Log (ITL), which remains responsible for verifying the accuracy and validity of those transactions;
- The transaction log and registries continue to reconcile their data with each other in order to ensure data consistency and facilitate the automated checks of the ITL;

- The requirements of paragraphs 44 to 48 of the Annex to Decision 13/CMP.1 concerning making non-confidential information accessible to the public would be fulfilled by each Party individually;
- All registries reside on a consolidated IT platform sharing the same infrastructure technologies. The chosen architecture implements modalities to ensure that the consolidated national registries are uniquely identifiable, protected and distinguishable from each other, notably:
  - With regards to the data exchange, each national registry connects to the ITL directly and establishes a distinct and secure communication link through a consolidated communication channel (VPN tunnel);
  - The ITL remains responsible for authenticating the national registries and takes the full and final record of all transactions involving Kyoto units and other administrative processes such that those actions cannot be disputed or repudiated;
  - With regards to the data storage, the consolidated platform continues to guarantee that data is kept confidential and protected against unauthorized manipulation;
  - The data storage architecture also ensures that the data pertaining to a national registry are distinguishable and uniquely identifiable from the data pertaining to other consolidated national registries;
  - In addition, each consolidated national registry keeps a distinct user access entry point (URL) and a distinct set of authorisation and configuration rules.

Following the successful implementation of the CSEUR platform, the 28 national registries concerned were re-certified in June 2012 and switched over to their new national registry on 20 June 2012. During the go-live process, all relevant transaction and holdings data were migrated to the CSEUR platform and the individual connections to and from the ITL were re-established for each Party.

The following changes to the national registry of Luxembourg have occurred in 2015:

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.

Reporting Item	Description
<p>15/CMP.1 annex II.E paragraph 32.(c)</p> <p>Change to database structure or the capacity of national registry</p>	<p>There was no change to the database structure as it pertains to KP functionality in 2015.</p> <p>Versions of the CSEUR released after 6.3.3.2 (the production version at the time of the last Chapter 14 submission) introduced minor changes in the structure of the database.</p> <p>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 is provided in Annex A.</p> <p>No change to the capacity of the national registry occurred during the reported period.</p>
<p>15/CMP.1 annex II.E paragraph 32.(d)</p> <p>Change regarding conformance to technical standards</p>	<p>Changes introduced since version 6.3.3.2 of the national registry are listed in Annex B.</p> <p>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 carried out in February 2016 and the test report is attached.</p> <p>No other change in the registry's conformance to the technical standards occurred for the reported period.</p>
<p>15/CMP.1 annex II.E paragraph 32.(e)</p> <p>Change to discrepancies procedures</p>	<p>No change of discrepancies procedures occurred during the reported period.</p>
<p>15/CMP.1 annex II.E paragraph 32.(f)</p> <p>Change regarding security</p>	<p>No change of security measures occurred during the reporting period.</p>
<p>15/CMP.1 annex II.E paragraph 32.(g)</p> <p>Change to list of publicly available information</p>	<p>No change to the list of publicly available information occurred during the reporting period.</p>
<p>15/CMP.1 annex II.E paragraph 32.(h)</p> <p>Change of Internet address</p>	<p>No change of the registry internet address occurred during the reporting period.</p>



Reporting Item	Description
<p>15/CMP.1 annex II.E paragraph 32.(i)</p> <p>Change regarding data integrity measures</p>	<p>No change of data integrity measures occurred during the reporting period.</p>
<p>15/CMP.1 annex II.E paragraph 32.(j)</p> <p>Change regarding test results</p>	<p>Changes introduced since version 6.3.3.2 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.</p> <p>Annex H testing was carried out in February 2016 and the test report is attached.</p>

## **15 Information on minimization of adverse impacts in accordance with Article 3, paragraph 14**

-> No changes occurred since the last submission (NIR 2014) - 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 guarantees 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/](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.*

#### Market imperfections:

Luxembourg has reformed its energy markets to a large extent to reduce market imperfections and in order to comply to 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.

#### Fiscal incentives:

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 CO2 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 fund set up in Luxembourg to deal with the Kyoto "flexible mechanisms" and is labeled "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 country 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

## **References**

All references used in the national inventory report must be listed in the references list.

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## **Chapter 5: Agriculture (CRF Sector 3)**

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## **Chapter 6: LULUCF(CRF Sector 4)**

See footnotes in the chapter itself

## **Chapter 7: Waste (CRF Sector 5)**

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